No 178 (178) (2026)

The scientific heritage
(Budapest, Hungary)
The journal is registered and published in Hungary.
The journal publishes scientific studies, reports and reports about achievements in different scientific fields.
Journal is published in English, Hungarian, Polish, Russian, Ukrainian, German and French.
Articles are accepted each month.
Frequency: 24 issues per year.
Format - A4
ISSN 9215 — 0365

All articles are reviewed
Free access to the electronic version of journal
Edition of journal does not carry responsibility for the materials published in a journal.
Sending the article to the editorial the author confirms it's uniqueness and takes full responsibility for possible consequences for breaking copyright laws

Chief editor: Biro Krisztian
Managing editor: Khavash Bernat

- Singula Aleksandra - Professor, Department of Organization and Management at the University of Zagreb (Zagreb, Croatia)
- Bogdanov Dmitrij - Ph.D., candidate of pedagogical sciences, managing the laboratory (Kiev, Ukraine)
- Chukurov Valeriy - Doctor of Biological Sciences, Head of the Department of Biochemistry of the Faculty of Physics, Mathematics and Natural Sciences (Minsk, Republic of Belarus)
- Torok Dezso - Doctor of Chemistry, professor, Head of the Department of Organic Chemistry (Budapest, Hungary)
- Filipiak Pawel - doctor of political sciences, pro-rector on a management by a property complex and to the public relations (Gdansk, Poland)
- Flater Karl - Doctor of legal sciences, managing the department of theory and history of the state and legal (Koln, Germany)
- Bence Orban - Doctor of sociological sciences, professor of department of philosophy of religion and religious studies (Miskolc, Hungary)
- Feld Ella - Doctor of historical sciences, managing the department of historical informatics, scientific leader of Center of economic history historical faculty (Dresden, Germany)
- Owczarek Zbigniew - Doctor of philological sciences (Warsaw, Poland)
- Gál Jenő - MD, assistant professor of history of medicine and the social sciences and humanities (Budapest, Hungary)
- Borbély Kinga - Ph.D, Professor, Department of Philosophy and History (Kosice, Slovakia)
- Eberhardt Mona - Doctor of Psychology, Professor, Chair of General Psychology and Pedagogy (Munich, Germany)
- Kramarchuk Vyacheslav - Doctor of Pharmacy, Department of Clinical Pharmacy and Clinical Pharmacology (Vinnytsia, Ukraine)

«The scientific heritage»
Editorial board address: Budapest, Kossuth Lajos utca 84,1204
E-mail: public@tsh-journal.com
Web: www.tsh-journal.com

CONTENT

ARCHITECTURE

Osypov O., Firsov D., Bondarenko M.
JUSTIFICATION OF RATIONAL METHODS OF INSTALLATION OF PVC WINDOW STRUCTURES.....4

ART STUDIES

Baimukhanova Zh.
THE DIDACTIC METHOD AND MODERN APPLICATION IN THE PRINCIPLES OF SCENIC SOLUTIONS OF THE EUROPEAN THEATER OF THE CLASSICAL ERA 9

CHEMISTRY SCIENCES

Kostiuk R., Horak Yu., Sobechko I.
THERMODYNAMIC PROPERTIES OF DERIVATIVES OF 2-METHYL-5-PHENYL-1R-1H-PYRROLE-3-CARBOXYLIC ACIDS IN THE CONDENSED STATE 14

CULTUROLOGY

Hrebnieva I.
THE EVOLUTION OF THE INTERPRETATION OF MOZART'S VIOLIN CONCERTOS IN THE XX AND XXI CENTURIES 19

ECONOMIC SCIENCES

Kozhakhmetov Z.
INNOVATION, ENTREPRENEURSHIP, ROUTINES AND BUSINESS: AN EVOLUTIONARY-INSTITUTIONAL MODEL OF ECONOMIC ACTIVITY TRANSFORMATION 24

Otargaliyev N.
AREAS FOR IMPROVEMENT IN THE CURRENT HEALTHCARE FINANCING MECHANISM IN KAZAKHSTAN 27

GEOGRAPHICAL SCIENCES

Aliyeva T., Farajova A.
THE EVOLUTION OF THE SUSTAINABLE DEVELOPMENT CONCEPT IN THE NAKHCHIVAN AUTONOMOUS REPUBLIC.....30

MEDICAL SCIENCES

Abdimomunova B.,Chandu, Mohitha, Venu Gopal, Jayanth, Priya, Shashank
THE ROLE OF ATYPICAL LYMPHOCYTES IN DIAGNOSIS OF EBV INFECTIOUS MONONUCLEOSIS 33

Abdimomunova B., Ain uddin, Heeba, Prateek, Ilma, Arbaz, Koushik
DIPHTHERIA IN INDIA: TRENDS, ANTITOXIN AVAILABILITY, AND CHALLENGES IN EARLY DIAGNOSIS 37

Noniashvili M., Kandashvili T., Giorgadze L.
THE DIAGNOSTIC VALUE OF ULTRASOUND ARTIFACTS IN THE MANAGEMENT OF COVID-19 PNEUMONIA ..42

PEDAGOGICAL SCIENCES

Ibrahimova A.
RE-EDUCATION - A PSYCHOLOGICAL APPROACH.....53

Ibrahimov F., Ibrahimova A.
THE “EDUCATION→ENGINEERING←ARTIFICIAL INTELLIGENCE” PARADIGM OF PUBLIC ACTIVITY IN THE “TECHNO-DEMOCRATIC-INFORMATION SOCIETY” 58

Zhumagazin Zh.
THE ROLE OF VOCAL TRAINING IN THE PROFESSIONAL DEVELOPMENT OF MUSICAL DRAMA STUDENTS 65

PHILOLOGICAL SCIENCES

Adigozalova L.
CROSS-LINGUISTIC SPORTS TERMINOLOGY: TYPOLOGICAL, DESCRIPTIVE, AND COMPONENTIAL ANALYSES OF AZERBAIJANI AND RUSSIAN LEXICAL SYSTEMS.....69

TECHNICAL SCIENCES

Burak L., Samankova N.
CONTEMPORARY INNOVATION IN SUSTAINABLE FRUIT AND VEGETABLE PROCESSING: REVIEW.....74

Roh K.
COMPARISON OF THE STABILITY OF PROBABILISTIC ID MODELS IN CONDITIONS OF STRICT COMPLIANCE WITH CONFIDENTIALITY REQUIREMENTS.....85

ARCHITECTURE

JUSTIFICATION OF RATIONAL METHODS OF INSTALLATION OF PVC WINDOW STRUCTURES

Osypov O.
Doctor of Technical Sciences, Professor
ORCID: 0000-0002-5463-3976
Kyiv National University of Construction and Architecture
Firsov D.
Postgraduate student of the Department of Construction Organization and Management,
ORCID: 0000-0002-9071-8336
Kyiv National University of Construction and Architecture
Bondarenko M.
Postgraduate student of the Department of Construction Organization and Management,
ORCID: 0000-0002-9071-8336
Kyiv National University of Construction and Architecture
DOI: 10.5281/zenodo.18614834

Abstract

Rational methods for the installation of polyvinyl chloride (hereinafter referred to as PVC) window structures in residential buildings are developed based on the principle of guaranteed comfortable living space (namely, a comfortable microclimate, specific sound insulation, and long-term durability). They also take into account design features and technical conditions; in the case of existing buildings, it is necessary to conduct an assessment of characteristic damages and defects, work conditions, and organizational constraints.

The research and justification of rational methods apply not only to multi-story buildings but also to private housing and, notably, architectural monuments. This is because the replacement or repair of translucent building envelopes must not compromise the integrity of the building's energy-efficient shell and must preserve the building's original appearance. Furthermore, maintaining both a comfortable indoor climate and the building's architectural and historical identity is of paramount importance.

The determination of installation methods and technologies has been addressed in numerous works both in Ukraine and abroad; however, these primarily focus on major structural elements. The selection of installation technologies for PVC translucent structures is carried out by the construction developer and the contractor, based on current regulatory legislation and economic feasibility. [2–4].

Keywords: window systems, installation methods, current trends in application, influencing factors, low-operation installation systems, technology selection, architecture, restoration, historical identity, translucent building envelopes.

The research and justification of rational installation methods for PVC translucent building envelopes are based on the following principle: the installation technology must ensure high-productivity execution of the entire complex of construction and assembly works. Simultaneously, it must guarantee the energy efficiency of the building shell, sound insulation, and the operational durability of the installation joint throughout the building's long-term lifecycle. Furthermore, buildings classified as architectural monuments must be addressed separately, as installation in such structures must comply with specific requirements tailored to this class of buildings [1].

The principle is implemented through sequential research and justifications, consisting of the following stages:

1. The systematization and generalization of construction-technological characteristics and working conditions during installation; and based on these, the establishment of a system of method-forming features that describe the specific installation requirements for residential buildings, the construction-technological characteristics of the window opening, its technical condition, and its nature. Attention must be paid to works performed on architectural monuments, as we must preserve their architectural and historical identity [7].

2. Research and justification of rational installation methods for window structures based on the identified system of method-forming features, which accounts for installation conditions, the necessity of additional works, as well as technical state specifics and the presence of characteristic types of openings.

3. Research and justification of rational technological solutions and parameters for the installation of window structures within substantiated groups of methods.

Stage One. The justification of the system of method-defining criteria is carried out through a systematic analysis and generalization of construction-technological characteristics. These describe the type, structural design, and technical condition, equipment and technology, the type and nature of the installation, as well as the specifics of the spatial-planning and structural solutions of the residential building and the conditions for performing construction and assembly works [10].

The result of the systematization and generalization of construction-technological characteristics is a scientifically substantiated system of method-defining

criteria, various combinations of which determine a characteristic production-technological situation.

Stage Two. The research and justification of rational installation methods for PVC window structures are conducted based on the identified system of method-defining criteria.

So, the result of the second stage of the research is a scientifically substantiated system of installation methods for residential window structures, the application of which guarantees specific performance characteristics and the reliable operation of the building.

Stage Three. The substantiation of organizational-technological models for installation workflows is carried out using structural analysis methods applied to the identified groups of methods, based on organizational-technological models developed for each set of method groups.

The result of the research is a scientifically substantiated set of rational technological parameters and solutions that establish the structure and sequence of construction processes, technological parameters, interdependencies, and organizational constraints, the application of which ensures the reliable and safe performance of window structures throughout their entire service life.

Based on the systematization and generalization of construction-technological characteristics and working conditions during the installation of window structures, the following can be adopted as method-defining criteria [5]:

A-criterion. Method for the installation or replacement of window structures.

a_1 - mass installation of window structures in new construction;

a_2 - full or partial replacement of window structures in an existing building;

a_3 - fragmentary replacement or repair of window structures in an existing building.

B- criterion. Parameters of the work front [8].

b_1 - spatial parameters of the work front (number of stories, zones, and work sections);

b_2 - technological parameters of the work front (work volumes and labour intensity of processes);

b_3 - time parameters (installation deadlines, intensity, cyclicity module, flow step, and flow rate);

C- criterion. Techniques for performing installation operations [6].

c_1 - installation with joint insulation using sealing tapes (e.g., membranes/tapes);

c_2 - installation with joint insulation using liquid sealants (e.g., liquid membranes or mastics);

c_3 - out-of-plane (bracket-based) installation: VSThermo/blaugelb Triotherm systems/illbruck;

c_4 - out-of-plane (bracket-based) installation: VEKAFAST system.

D- criterion. Technological feasibility of the installation process.

d_1 - availability of a system of specialized mechanization tools and equipment;

d_2 - availability of a system of specialized construction rigging and inventory;

d_3 - low-operation (minimal step) nature of the window structure installation process;

d_4 - labour intensity of preparatory and auxiliary operations.

E-criterion. Technical condition and the presence of previous modernizations and interventions in the existing building.

e_1 - technical condition of the structures and the building as a whole;

e_2 - nature and degree of damage to the wall infill and window structures;

e_3 - presence of previous modernizations and interventions in the existing building.

F-criterion. Types and methods of restoration for architectural monuments, window, and door structures.

f_1 - analytical restoration;

f_2 - synthetic restoration;

f_3 - restoration with adaptation;

f_4 - conservation.

Analytical restoration involves restoring the functional properties of windows without recreating the original aesthetic appearance of the units as a whole or their individual components.

Synthetic restoration aims to reproduce and reinforce window structures using modern PVC window technologies—specifically appropriate window and door systems, installation techniques, and specialized mounting joint configurations.

Restoration with adaptation involves a comprehensive scope of work featuring the complete replacement of windows while preserving an appearance identical to the original; this approach is aimed at improving functional and energy-efficiency properties.

Conservation is directed at the reinforcement and protection of both the building as a whole and the window opening. It involves the application of specialized materials and specific types of PVC profiles.

The formation of rational installation methods is carried out as a decision-synthesis process, consisting of sequential procedures for organizing the initial system of methods using system-forming factors (Fig. 1).

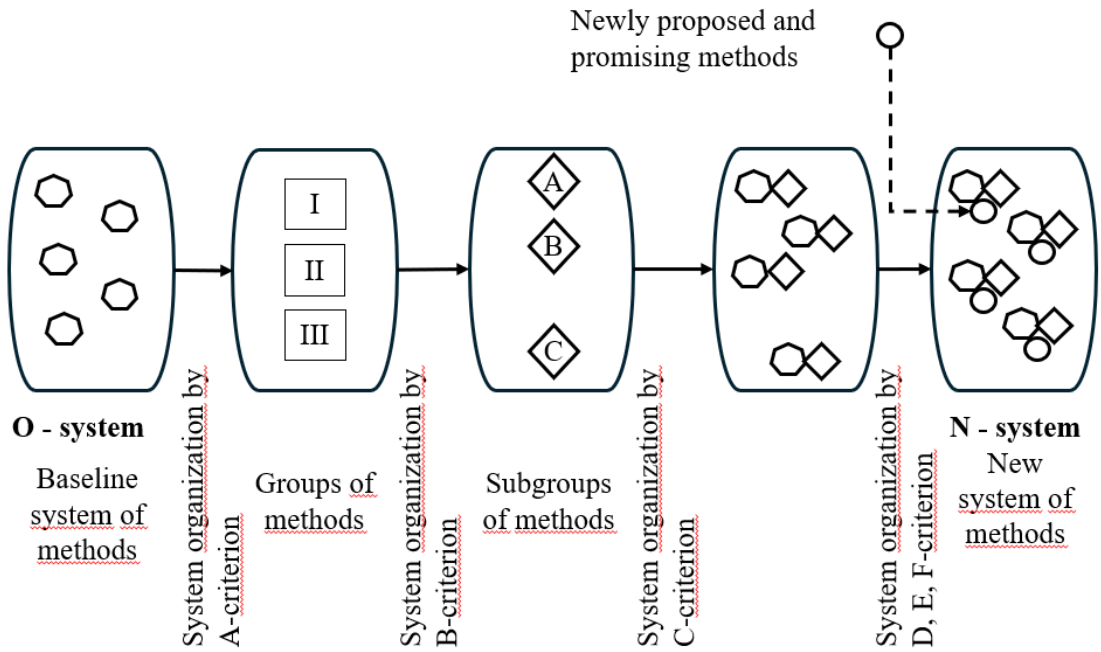


Fig.1 Procedural-logistical scheme for the formation of rational installation methods for PVC translucent structures.

These factors consist of method-defining criteria, which allow for the organization of the initial system of methods into groups intended to realize the primary installation functions (installation, replacement, or repair). These, in turn, are subdivided into subgroups of methods that reveal the essence of the processes and phenomena underlying the transformation of material elements into construction products. Furthermore, these include methods categorized by technological features (such as the use of tapes or sealants, the application of supplementary installation systems, or the use of restoration materials, among others).

During the stages of forming the B-system (method subgroups) and the C, D, E, and F-systems (methods), new structural elements are introduced that possess functional, constructive, and technological substantiation.

As science and technology advance, the structures of the B-system and the C, D, E, and F-systems can be augmented with new, promising elements.

Consequently, the system of installation methods for residential window structures is established as an open, evolving system.

Window installation methods are formed by taking into account all possible combinations of the method-defining criteria – $B = \{b_1, b_2, b_3\}$, $C = \{c_1, c_2, c_3, c_4\}$, $D = \{d_1, d_2, d_3, d_4\}$, E = $\{e_1, e_2, e_3\}$, F = $\{f_1, f_2, f_3, f_4\}$ established on the basis of a previously conducted construction-technological analysis of the parameters and installation conditions in residential buildings.

Window installation methods are developed for the previously identified groups of methods, namely: I. Mass installation of new structures; II. Replacement of existing structures; III. Partial replacement or repair of structures.

Within the mass installation of window structures (***Group I***), three distinct methods can be identified: I_a – vertical (sectional) method; I_b – horizontal (floor-by-floor or tier-by-tier) method; and I_c – mixed method.

The vertical (sectional) installation method involves performing work within separate sections, which can significantly accelerate the overall commissioning deadline of the building.

The horizontal (floor-by-floor or tier-by-tier) method is utilized when performing work across a wide work front [9].

The mixed method is utilized in the combined construction of high-rise buildings featuring stylobate sections.

For the replacement of existing structures (***Group II***), two main subgroups can be identified: – replacement of structures during capital renovation, and – replacement of structures following destruction.

Replacement during capital renovation involves the complete dismantling of existing glazing and the installation of new translucent structures into prepared openings that comply with current legislation.

Replacement following destruction involves the removal of damaged structural remains, the restoration (reinforcement, strengthening) and preparation of the opening, and the installation of new translucent structures [7].

These subgroups involve the application of methods similar to those in the first group, namely: II_a – vertical (sectional) method, II_b – horizontal (floor-by-floor or tier-by-tier) method, and II_c – mixed method.

For partial replacement or repair (***Group III***), two subgroups can be identified: partial replacement of window structures within an individual apartment or a specific area of an apartment, and the repair of existing structures (replacement of the sash, gaskets, hardware, or insulated glass units) or the installation of additional elements (roller shutters, mosquito nets, or external reinforcements).

These subgroups form the following methods: III_a – the discrete method, and III_b – the fragmentary method.

The discrete method is characterized by the replacement of individual structures within an apartment or across a building facade.

The fragmentary method is used when performing repair work within a single structure (for example, replacing a portion of the structure or repairing a specific structural element, such as a sash, etc.).

The conducted research on the development and substantiation of window installation methods has enabled the creation of a classification based on these defining attributes.

Architectural monuments require a more meticulous approach to preserving their identity and occupy a distinct segment of methods with specific subgroups, namely:

- Window Restoration (Group A): A.1. Shape stabilization, A.2. Restoration of physical properties, A.3. Repair and modernization;
- Window Recreation (Group B): B.1. Recreation of the original form, B.2. Recreation of structural integrity;
- Window Replacement (Group C): C.1. Sealing of installation joints, C.2. Full replacement with modern systems;
- Window Reinforcement (Group D): D.1. Reinforcement of load-bearing window elements, D.2. Installation of reinforcing and protective structures.

For each subgroup of methods, specific techniques and the conditions for their application have been established:

A.1. Shape stabilization.

A.1.1. Application of reinforcing materials to strengthen load-bearing window elements. Provides reinforcement for statically loaded window components (mullions/transoms) using surface-mounted reinforcing profiles.

A.1.2. Application of fastening and/or reinforcing elements for individual window parts. Ensures the stabilization of the frame and sash geometric dimensions by installing metal corner brackets, plates, and rails to reinforce window components.

A.2. Restoration of Physical Properties.

A.2.1. Repair of cracks and joints in structural elements. Involves the remediation of cracks in the corners of PVC windows and doors using specialized repair materials for sealing and extending the service life of the structure.

A.3. Repair and Modernization.

A.3.1. Application of a renovation (replacement) frame. Utilized for installing a new PVC window when the removal of the old wooden frame is impossible due to the risk of damaging the masonry opening.

A.3.2. Repair of load-bearing window elements. Applied when a window mullion requires replacement (due to deformation, failure, etc.) to restore the structural load-bearing capacity.

A.3.3. Hardware replacement. Intended for cases involving the loss of functional properties of individual hardware components, or for window modernization without full replacement.

A.3.4. Glass unit replacement. Used to improve the overall energy efficiency of the window by replacing the glass unit with one utilizing low-emissivity (Low-E) glass.

A.3.5. Seal/Gasket replacement. This method is applied in cases of damage or degradation to restore essential window performance characteristics (air permeability and water tightness).

B.1. Recreation of Form.

B.1.1. Application of PVC structural elements. This method is applied to existing PVC windows when replacing or modernizing specific components to recreate the original aesthetic appearance.

B.1.2. Application of PVC repair materials. This method is used to repair the decorative surface of the window profile by applying repair lamination films.

B.2. Recreation of Structural Integrity.

B.2.1. Replacement of individual PVC window elements. This method involves replacing the sash, mullion, or decorative profile to restore structural integrity.

C. 1. Sealing of Installation Joints.

C.1.1. Application of hydro-/vapor-insulation materials. This method involves sealing the window junctions to prevent moisture penetration and subsequent deterioration of the masonry opening using vapor/hydro-insulation tapes or liquid membranes.

C.2. Full Replacement with Modern Systems.

C.1.1. Window replacement with a new PVC unit. This method is used when it is impossible to repair, restore, or recreate the form and external appearance of the window.

D.1. Reinforcement of Load-bearing Window Elements.

D.1.1. Application of fasteners, anchors, chemical anchors, etc. This method involves reinforcing the window's fixation depending on the condition of the masonry opening, the wall material, etc.

D.1.2. Application of external surface-mounted reinforcing elements. This involves the use of surface-mounted reinforcing components for the mullions of an existing PVC window.

D.2. Installation of Reinforcing and Protective Structures.

D.2.1. Application of a renovation frame. This method involves installing a new PVC window using a renovation frame while retaining the existing frame within the opening.

D.2.2. Application of a renovation frame. This method involves installing a new PVC window using a renovation frame while retaining the existing frame within the opening.

Summary

The obtained results of the classification of methods allow us to draw certain conclusions regarding the areas of application.

Installation methods with seam sealing using tapes or liquid sealants are more often used at mass construction sites of multi-storey buildings, work on sealing installation seams can be performed by both installation teams of window construction contractors and contractors performing facade work.

To obtain higher energy efficiency indicators of the building, we can use methods using remote installation systems. Currently, the market of developers and

suppliers of remote systems is limited to four companies: three companies manufacture a remote installation system from high-density and plastic polystyrene foam (VSThermo, blaugelb Triotherm, illbruck), and one company provides the market with a remote installation system from PVC (VEKAFast). In addition, for work in architectural monuments, the system developer of PVC window systems provides the opportunity to use appropriate profiles for restoration.

References

1. Barashykov A. Ya. Otsiniuvannia tekhnichnoho stanu budivel ta inzhenernykh sporud; navch. posib. dlia stud. vyshchykh navch. zakl. / A. Ya. Barashykov, O. M. Malyshev – K.: Osnova, 2008.

2. DSTU B.V.2.6-79:2009 «Konstruktsii budynkiv i sporud. Shvy ziednuvalni mists prymykan vikonnykh», Minrehionbud Ukrainy. 2009.

3. DSTU EN 14351-1:2020 «Vikna ta dveri. Vymohy. Chastyna 1», Kyiv. 2020.

4. Halushko V. O. Shliakhy pidvyshchennia nadiinosti ta dovhovichnosti zhytlovykh budynkiv: Monohrafiia / V. O. Halushko. – Zaporizhzhia: KPU, 2008.

5. Hrabovetskyi B. Ye. Metody ekspertnykh otsinok: teoriia, metodolohiia, napriamky vykorystannia: monohrafiia / [B. Ye. Hrabovetskyi.] — Vinnytsia: VNTU, 2010.

6. Leitfaden zur Planung und Ausführung der Montage von Fenstern und Haustüren für Neubau und Renovierung. - ISBN: 978-3-00-045381-6

7. Livinskyi O. M. Problemy i metody rekonstruktsii ta remontu zhytlovoho fondu / O. M. Lyvynskyi, O. O. Omelchenko, Yu. O. Pishchalenko, A. B. Rodiontsev // Budivnytstvo Ukrainy. – 1996.

8. Lytvyn V. Montazhnyk vikonnykh ta dvernykh konstruktsii: navch. posib.: do navch. kursu "Montazhnyk vikonnykh ta dvernykh konstruktsii" dlia pidvyshchennia kvalifikatsii ta otrymannia chastk. prof. kvalifikatsii i dod. kompetentnostei iz tekhnolohichno sumizhnykh profesii bud. haluzi / [V. Lytvyn ta in.]. - Odesa: Helvetyka, 2023. - ISBN 978-617-554-128-9

9. Meneiliuk A. Y. Sovremennye tekhnolohyy v stroytelstve: Uchebnyk; 3-e yzdanye, dop. y per. / [A. Y. Meneiliuk, V. S. Dorofeev, L. E. Lukashenko y dr.] – K.: Osvita Ukrainy, 2011.

10. Osypov A. F. Analiz i prohnozuvannia osnovnykh tendentsii i napriamkiv prohresu v budivnytstvi / A. F. Osypov, Ye. H. Romanushko // Metodychni rekomendatsii dlia studentiv spetsialnosti 8.092101 “Promyslove ta tsyvilne budivnytstvo”. – K.: KNUBA, 2000.

ART STUDIES

ДИДАКТИЧЕСКИЙ МЕТОД И СОВРЕМЕННОЕ ПРИМЕНЕНИЕ В ПРИНЦИПАХ СЦЕНОГРАФИЧЕСКИХ РЕШЕНИЙ ЕВРОПЕЙСКОГО ТЕАТРА КЛАССИЧЕСКОЙ ЭПОХИ

Баймуханова Ж.А.
Магистр искусств, доцент кафедры «Сценография»
Казахской национальной академии искусств имени Темирбека Жургенова
Алматы, Казахстан

THE DIDACTIC METHOD AND MODERN APPLICATION IN THE PRINCIPLES OF SCENIC SOLUTIONS OF THE EUROPEAN THEATER OF THE CLASSICAL ERA

Baimukhanova Zh.
Master of Arts, Associate Professor of the Department of «Scenography»
Temirbek Zhurgenov Kazakh National Academy of Arts
Almaty, Kazakhstan
DOI: 10.5281/zenodo.18614845

Аннотация

В статье рассматривается дидактический метод в сценографии европейского театра классической эпохи, анализируются его принципы в контексте образовательных целей и современного применения, а также исследуется влияние сценографии на восприятие спектакля. Изучение принципов сценографии классического европейского театра и новая визуальная коммуникация в казахских постановках.

Abstract

The article examines the didactic method in the scenography of the European theater of the classical era, analyzes its principles in the context of educational goals and modern applications, and examines the influence of scenography on the perception of the performance. The study of the principles of set design of classical European theater and new visual communication in Kazakh productions.

Ключевые слова: сценография, европейский театр, казахский театр, новые технологии, визуальные наративы, дидактический метод.

Keywords: scenography, European theater, Kazakh theater, new technologies, visual narratives, didactic method.

Введение. В комплексном направлении сценографического решения спектакля, которое развивалось от классических декораций к многофункциональным пространствам вытекают из используемых новых технологии и интерактивных элементов в современном театре. Ее современная траектория предполагает отказ от простого изображения места действия в пользу создания символических, абстрактных и действенных образов. А также вливает интеграцию света, звука и видео как полноценных элементов постановки. Основные модели развития включают смещение акцента с декоративности на символическое и действенное оформление, что делает сценографию инструментом драматургии, а не только фоном. Если раньше главная функция сценографии заключалась в изображении места действия, то сегодня она все чаще использует символы и абстракцию для создания многозначных образов и усиления эмоционального воздействия спектакля.

Обзор литературы охватывает работы авторов: Г.Н.Бояджиев, А. К.Дживелегов, В.И.Березкин, Ю.Е.Шур, Ж.А.Баймуханова. Применяя дидактический подход в обработке информации для лекций и выполнения самостоятельных работ включает структурирование информации по принципам дидактики, организацию учебного процесса через взаимосвязанные методы и средства, а также ориентацию на достижение педагогических целей, а именно дифференциации по сложности для обеспечения эффективного усвоения. Важные направления исследований включают: анализ классических театральных форм (греческая трагедия, римская комедия), изучение развития сценографии в эпоху Возрождения и барокко, а также исследование современных интерпретаций дидактических функций сценографии в постмодернистском театре.

Зарождение ранне классической эпохи возникло еще в 16-ом веке, в эпоху великих географических открытий, начала колониальных захватов, реформаций, крестьянских войн и первых буржуазных революций. Время удивительно нового создания науки и искусства, формирования нового мировоззрения. Огромную роль в этом процессе сыграло противостояние двух подходов к религии: протестантизма и вызванное им к жизни контрреформации.

Прямым продолжением традиций художественной культуры эпохи Возрождения стал новый художественный стиль, сформировавшийся к началу 17-го века и названный классицизмом. Это слово происходит от итальянского термина classicus, то есть образцовый. Однако в отличие от великих мастеров прошлого основное внимание художники эпохи классицизма уделяли отражению в своих творениях идее гармонического устройства общества. Они считали, что Древний Рим и Греция

как раз и были такими идеальными обществами. Поэтому в своих творениях они так часто обращались к античным сюжетам, возрождали в архитектуре портики, колонны, статуи, рельефы, систему ордеров. Их произведения обладали исключительной простотой и геометрической правильностью, и это не случайно.

Такое явление, как «ученная» драматургия создает принципы сценической выразительности, принципы сценического театра, устройства театра, дарит первых продюсеров, директоров, полную организацию театрального коллектива театрального здания. Это самое важное, что делает это явление. Вместе с этим, она просвещает общество.

Новая форма драматургии, написанная по примеру античных драм, приобретает новых авторов, ученных гуманистов. Среди них – Никколо Макиавелли, написавший отрясающую комедию «Мандрагору» актуальную и сегодня, Пьетро Аретино и Джордано Бруно. Многих из таких новаторов мысли не обошел суд инквизиции. Опыт «ученной драмы» вместе с совокупностью богатой национальной культурой, античной культурой и культурой различных итальянских городов вырастает в определенно новый жанр, который меняет вообще роль театра, действие театра, потому что «ученая комедия» и «ученая трагедия» имеет порицательный, и нарицательный образ, из нее уходит карнавальность, постепенно перестает нести совершенно развлекательный характер.

Повсеместная commedia dell'arte заставила полюбить посещение театра, платить за представление. Этот процесс смог продержаться до конца 18-го века, однако рождает большое количество квалифицированных артистов, драматургов: Карло Гоцци, Карло Гольдони, театральных групп: «Джелози», «Конфиденти», «Федели». Они гастролируют по всей Европе, некоторые оседают на постоянное пребывание, как театр «Комеди Итальенн» в Париже. Революционное преобразование театра делает театр полноправной частью жизни людей.

В Англии концу 16-го века одна за другой начинают формироваться актерские труппы, и они постепенно уходят с площадных подмостков, игравшие сначала во дворах гостиниц, потом в специальных театральных зданиях (первый построил актер и предприниматель Джеймс Бербедж -- Театр): Роза, Лебедь, Глобус, Фортуна.

В эпоху классицизма драматургический канон единства места и времени действия способствовал господству несменяемой декорации (тронный зал, вестибюль дворца в трагедии, городская площадь, комната — в комедии), поэтому всё богатство декорационно-постановочных эффектов сосредоточилось в оперно-балетном жанре. Итальянские мастера (А. Поццо, художники из семейства Галли-Биббиена) нарушили симметрию декораций 17-го века, ввели угловую перспективу, усилив средствами живописи иллюзию глубины; добиваясь большей масштабности путём изображения отдельных архитектурных частей вместо целого здания, они форсировали контрасты света и тени. В эпоху Просвещения мастера театрально-декорационного искусства обращались к героизированным образам античности (работавшие во Франции Дж. Н. Сервандони, Г. Дюмон, П. А. Брюнетти). В конце 18 в., в связи с развитием буржуазной драмы, появились декорационные павильоны. В России 18 в. к оформлению спектаклей привлекались иностранные мастера — Дж. Валериани и П. ди Г. Гонзаго и др.

В 17—18 вв. в странах Азии кризис феодальной идеологии привёл и к нововведениям в сценографии. В Японии в 18 в. сооружались здания для театров Кабуки, сцена которых имела просцениум, горизонтально раздвигающийся занавес, идущие через зал помосты-«ханамити» («дороги цветов»); в 1758 здесь была введена вращающаяся сцена. Средневековые традиции вплоть до 20 в. сохранились во многих театрах Индии, Индонезии, стран Индокитая, где оформление ограничивается главным образом костюмами, масками и гримами.

Великая французская революция оказала значительное воздействие на театрально-декорационное искусство. На сценах парижских «театров бульваров» высокое искусство театральных машинистов позволяло воспроизводить сцены кораблекрушений, пожаров и т. д.; распространились так называемые пратикабли (объёмные детали оформления, изображавшие скалы, мосты и т. д.). В 1-й четверти 19-го века Л. Ж. М. Дагер во Франции, Ч. Баркер в Англии демонстрировали панорамы и диорамы в сочетании с новшествами газового освещения (вводится в 1820-е гг.). Представители романтизма выдвинули требование исторически конкретной характеристики места действия (этому отвечали театральные работы французов Э. Делакруа, П. Делароша, Ж. Б. Изабе и др.). Декораторы и режиссёры П. Сисери, Ш. Сешан и Э. Деплешен во Франции, Ф. фон Дингельштедт в Германии создавали спектакли со сложными многокартинными декорациями и пышными костюмами, сочетая историческую точность с эффектной красивостью. Усложнение постановочной техники заставило применять занавес в перерывах между актами (впервые — в 1829 на сцене парижской «Гранд-Опера», а в 1849 здесь же — электрическое освещение). В России с 1830-х гг. главой школы «официального романтизма» был А. А. Роллер. Разработанная им техника постановочных эффектов развивалась К. Ф. Вальцем, А. Ф. Гельцером и др. Борьба со штампами роллеровской школы за национальное своеобразие сценографии и. была начата М. А. Шишковым и М. И. Бочаровым, но тормозилась условиями «казённой сцены», узкой специализацией театральных художников, делившихся на «пейзажных», «архитектурных» и других видов специализаций, а также повсеместным применением сборных и типовых декораций.

Огромное воздействие на декорационное искусство 1870—80-х гг. оказала деятельность Мейнингенского театра, режиссёры которого, стремясь преодолеть традиции итальянской кулисно-арочной системы, придавали сценическому рельефу многообразие, в изобилии применяя пратикабли и различные архитектурные формы. В изобразительных решениях мейнингенцев сказалось влияние немецкой исторической живописи 19-го века (П. фон Корнелиуса, В. Каульбаха и др.).

В конце 1870-х гг. с критикой идеализированных, самоцельно-феерических декораций выступил Э. Золя, призвавший к «точному воспроизведению социальной среды» (его последователями в сценическом натурализме были режиссёры А. Антуан во Франции и О. Брам в Германии). Борьбу с натурализмом возглавил театр французского символизма (художники М. Дени, П. Серюзье, А. де Тулуз-Лотрек, Э. Вюйяр, объединившиеся вокруг режиссёров П. Фора и О. М. Люнье-По и создававшие упрощённые, изысканно-стилизованные декорации, по образному строю близкие искусству «модерна»).

Последняя четверть 19-го века — эпоха расцвета русского театрально-декорационного искусства В. Д. Поленов, В. М. Васнецов, К. А. Коровин, В. А. Серов, М. А. Врубель утверждали принципы целостной поэтической трактовки спектакля, используя композиционные приёмы станковой живописи. Высокая живописная культура, тончайшее умение передать стиль и характер искусства различных эпох были свойственны мастерам сценографии, принадлежавшим к группировке «Мир искусства» (А. Н. Бенуа, Л. С. Бакст, М. В. Добужинский, Н. К. Рерих и др.); участвуя в организованных С. П. Дягилевым гастролях русской оперы и балета в Париже (так называемые Русские сезоны за границей, с 1907), эти мастера вывели русское театрально-декорационное искусство на мировую арену. Большое значение имело также творчество А. Я. Головина, добивавшегося особой парадной декоративности образных решений.

Казахский театр весь 20 век демонстрировал преемственность классического европейского театра как в драматических театрах, так и в постановках оперы и балета. Современные музыкальные постановки новых театров Астана Опера, Астана Балет и молодые драматические театры страны продолжают эту традицию, добавляя национальный колорит. А также, вторя новациям, активно экспериментируют и внедряют современные подходы технологий в своих новых постановках, и позволяет создавать сложные визуальные нарративы, которые могут иллюстрировать абстрактные концепции в том числе с национальным кодом. Изучение и исследование которых предстоит осмыслить и представить поколению будущего.

Результаты исследования. Осмысление параллелей основных характеристик сценографических решений значительно упрощается при составлении таблицы. Которая объединяет в столбцы (принципы) и строки (средства и применение). Использование подобной сетки структурирует анализ знаний, что делает ее удобным инструментом для представления и обработки информации по изучению данного предмета.

Принципы сценографии в сравнении классической эпохой и современной

№	Принципы классической эпохи	Средства сценографии	Принципы современной сценографии	Применение
1	Наглядность и дидактизм.	Декорации и костюмы создавались с целью наглядной демонстрации моральных истин и классических добродетелей, а не для создания реалистичной атмосферы.	Визуальная коммуникация.	Сценография становится языком, который напрямую сообщает идеи и смыслы.
2	Использование античных образцов.	Сценография была вдохновлена античным театром, что проявлялось в использовании классической архитектуры и мифологических сюжетов в декорациях	Усиление смысла.	Художественные средства, такие как символизм и абстракция, усиливают эмоциональное воздействие и делают образы многозначными, помогая зрителю глубже понять спектакль.
3	Иллюзорная перспектива.	В XVII-XVIII веках активно развивалась иллюзорная перспектива, создававшая эффект глубины и реалистичности, а также позволявшая подчеркивать пространственные и временные рамки действия.	Использование действенных средств.	Сценография может играть роль персонажей, создавать локации и даже выступать как инструмент передачи информации.
4	Символизм.	Декорации и костюмы несли символическое значение, помогая зрителю понять идеи и смыслы произведения.	Интеграция с режиссурой.	Тесная связь с общим творческим замыслом режиссера, где визуальные элементы служат инструментом для достижения общей цели спектакля.
5	Подчинение тексту.	В классической эпохе сценография была подчинена лите-	Создание эффекта отчуждения (остра-	**Пример:** Использование видимых элементов сцени-

		ратурному тексту и драматургии. Декорации служили фоном, который не отвлекал от содержания пьесы, а лишь помогал его раскрыть.	нения). Этот брехтовский прием направлен на разрушение иллюзии реальности.	ческого оборудования, незамаскированного света или показ конструкции декораций. Это напоминает зрителю, что он находится в театре, и побуждает критически осмысливать увиденное.
6	Чёткая иерархия жанров.	Сценографическое решение строго соответствовало жанру пьесы.	Символизм и метафоричность. Сценография не просто показывает место действия, а содержат определенный смысл или идею, подлежащую расшифровке.	**Пример:** Минималистичные, абстрактные декорации, где один предмет или форма может символизировать целую идею, социальную проблему или исторический период.
7	Для трагедий Для комедий	- использовались величественные декорации с архитектурными элементами, отсылающими к античности (храмы, дворцы), что подчёркивало возвышенность и героическую тему произведения. - создавались более реалистичные, но всё же типовые декорации, изображающие городские площади или жилые интерьеры, чтобы подчеркнуть сатирическую или нравоучительную направленность сюжета.	Интерактивность и прямое обращение. В современном театре сценография может быть интерактивной, вовлекая зрителя в процесс, чтобы превратить его из пассивного наблюдателя в активного участника.	**Пример:** Спектакли, где зрители могут перемещаться по сценической площадке или, где сценография меняется в ответ на их действия. Это превращает пространство в среду обучения через опыт.
8	Принцип трёх единств.	Сценография подчёркивала драматургические единства (места, времени и действия).	Документальность и исторические отсылки. Использование аутентичных предметов, фотографий или проекций, связанных с реальными событиями, может служить дидактическим целям. Такой подход информирует зрителя о реальном контексте, о котором идет речь в спектакле.	**Пример:** Включение архивных кадров или документов в видеопроекции, которые являются частью сценографии, для придания спектаклю большей исторической достоверности и образовательной ценности.
9	Типизированность и универсальность.	Классическая сценография избегала излишней детализации и индивидуализации. Вместо этого использовались типовые решения, которые были легко узнаваемы и понятны зрителю. Это способствовало тому, что моральный посыл воспринимался как универсальная истина, применимая к любому человеку.	**Современные технологии. Абстрактные концепции.**	Новые технологии, такие как видеомэппинг, дополненная реальность или цифровые проекции, предоставляют сценографам новые дидактические инструменты. Они позволяют создавать сложные визуальные нарративы, которые могут иллюстрировать абстрактные концепции или дополнять сюжет информацией, которая иначе осталась бы невысказанной

Список литературы:

1. The World Encyclopedia of Contemporary Theatre: The Americas (англ.) / Rubin, Don; Carlos Solórzano (англ.) русск.. — New York City: Routledge, 2000. — P. 394. — ISBN 0-415-05929-1.

2. Бояджиев, Г. Н. История западноевропейского театра от возникновения до 1789 года / Г. Н. Бояджиев, А. К. Дживелегов. – Москва; Ленинград: Государственное издательство "Искусство", 1941. – 615 с. – Режим доступа: по подписке. – URL: https://biblioclub.ru/index.php?page=book&id=130965 (дата обращения: 08.10.2021). – Текст: электронный.

3. Шур Ю.Е. Театральный журнал в России: генезис и типология: дис. ... канд. филол. наук: 05.25.03. М., 2014. 208 с.

4. Березкин В.И. Искусство сценографии мирового театра. Т 2. Второя половина XX века: В зеркале Пражских квадриеннале 1967—1999 годов. – М.: Эдиториал УРСС, 2001. – 808 с.

5. Баймуханова Ж.А. «Феномен новой визуальности в сценографии казахского театра второго десятилетия XXI в.» с. 132, март 2024г., ISBN 978-601-269-492-5 https://drive.google.com/file/d/1PGrva18w2g7ZiEVG0vsTnVNkXw21qZJy/view?usp=sharing

CHEMISTRY SCIENCES

THERMODYNAMIC PROPERTIES OF DERIVATIVES OF 2-METHYL-5-PHENYL-1R-1H-PYRROLE-3-CARBOXYLIC ACIDS IN THE CONDENSED STATE

Kostiuk R.
PhD student of 4rd year study of Institute of Chemistry and Chemistry Technologies, Lviv Polytechnic National University
Horak Yu.
Senior Research Officer of the Department of Organic Chemistry, Ivan Franko National University of Lviv, PhD Chem., Senior Research Officer.
Sobechko I.
Associate Professor of the Department of Physical, Analytical and General Chemistry, Lviv Polytechnic National University, DSc Chem., Associate Professor
DOI: 10.5281/zenodo.18614847

Abstract
According to the Paal–Knorr reaction, 1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid and 2-methyl-5-phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid were synthesized. The main stages of the synthesis were described, and the yields of the target products were determined. The structures of the synthesized compounds were confirmed by nuclear magnetic resonance spectroscopy, and the corresponding NMR spectra are reported.

The potential biological activity of the compounds was evaluated using the PLATO r36 web application. The changes in the internal energy of combustion, as well as the enthalpies of combustion and formation of the synthesized compounds in the condensed state, were experimentally determined using precision calorimetric equipment. Based on the experimental data obtained, the thermodynamic parameters were recalculated to the standard temperature of 298.15 K.

Keywords: enthalpy of combustion; enthalpy of formation; 1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid; 2-methyl-5-phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid.

Introduction

The development of the pharmaceutical market in the modern world is occurring at an exceptionally rapid pace. New compounds capable of exhibiting diverse biological activities are synthesized daily, including those containing heterocyclic fragments with a nitrogen atom in their structure [1–2]. It is well known that heterocyclic compounds play a crucial role in the metabolic processes of all living cells, while pharmacologically active heterocyclic systems find wide application in clinical practice [3].

One of the promising directions in contemporary pharmaceutical research is the imitation of structurally natural fragments to expand the range of action of medicinal agents. In particular, the introduction of various substituents into molecules allows significant modification of their physicochemical and biological properties, such as lipophilicity, polarity, water solubility, and selectivity, often achieved through bioisosteric replacements [4].

Among nitrogen-containing heterocyclic systems, pyrrole occupies a special place. This heterocycle is a component of numerous biologically active compounds of plant and animal origin. In particular, the pyrrole fragment is part of important biomolecules such as the enzyme catalase, the mold pigment prodigiosin, the bile pigment bilirubin, plant cell chlorophyll, heme, and vitamin B_{12} in animal cells [5–6].

Compounds containing a pyrrole fragment in their structure have demonstrated significant biological activity. They are widely used as fungicidal, antibacterial, antifungal, anti-inflammatory, antipyretic, antitumor, and antihyperlipidemic agents [5, 7–9]. In addition, such compounds are employed as therapeutically active substances [10], as well as cholesterol-lowering and antioxidant agents [11].

Given the high potential of pyrrole-containing compounds as components of medicinal drugs, this study focuses on the synthesis and investigation of the biological activity of 1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid and 2-methyl-5-phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid. The absence of basic thermodynamic parameters for these compounds in the literature, particularly the enthalpies of combustion and formation, necessitated their experimental determination within the framework of this research.

The obtained thermodynamic characteristics will allow optimization of the synthesis, processing, transportation, and storage processes of the studied substances. Furthermore, if necessary, the information on heat-generating capacity can be utilized during the disposal of these compounds by combustion in boilers, with subsequent recovery of released energy in heat exchange processes. This approach represents one of the simplest and most environmentally reasonable methods for the disposal of pharmaceutical compounds containing carbon, hydrogen, oxygen, and nitrogen atoms [12].

The aim of the study:

The aim of this study is to determine the main thermodynamic parameters of 1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid and 2-methyl-5-

phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid. Using the bomb calorimetry method, the combustion energy of the studied acids will be measured, and based on these data, the standard enthalpies of combustion and formation in the condensed state will be calculated. The obtained values of the phase transition parameters will then be recalculated to the commonly accepted temperature of 298.15 K.

Experimental

The synthesis of 2-methyl-5-phenyl-1R-1H-pyrrole-3-carboxylic acids was carried out according to the reaction scheme shown in Figure 1:

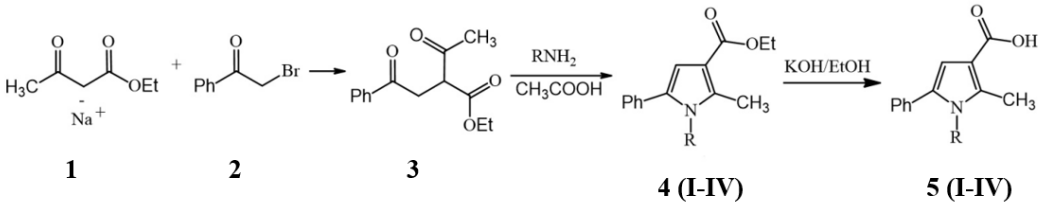


Figure 1. Synthesis of 2-methyl-5-phenyl-1R-1H-pyrrole-3-carboxylic acid derivatives.

The synthesis was performed in two stages:

Stage 1. A suspension of metallic sodium (0.03 mol), ground in 40 mL of toluene, was gradually treated with ethyl acetoacetate (0.044 mol) under cooling and vigorous stirring. The reaction mixture was maintained with stirring at room temperature for three days. After cooling to 283.15 K, phenacyl bromide (0.03 mol) was added to the mixture, which was stirred for 1 hour at this temperature, and then for an additional 24 hours at room temperature.

Upon completion of the reaction, the solid sodium bromide residues were removed by filtration, and the organic solvent (toluene) was evaporated under reduced pressure (30 mmHg). The resulting residue was distilled under vacuum; the boiling point was 448–450 K at 2 mmHg. As a result, ethyl 2-acetyl-4-oxo-4-phenylbutanoate (3) was obtained in a yield of 6.35 g (86%).

Stage 2. A quantity of 5.00 g (0.02 mol) of ethyl 2-acetyl-4-oxo-4-phenylbutanoate (3) was dissolved in 30 mL of cooled acetic acid, after which 0.02 mol of the corresponding amine was added. The reaction mixture was refluxed for 2.5 hours. After cooling, the mixture was diluted with 100 mL of water, and the formed viscous oils were extracted with dichloromethane. The organic phase was washed with water and dried over anhydrous sodium sulfate for 2 hours.

After removal of the solvent, an aqueous solution of potassium hydroxide (2.24 g, 0.04 mol) in 20 mL of ethanol was added to the crude ester (3). The mixture was heated for 15 minutes, cooled to room temperature, and then 50 mL of water was added. The solution was acidified with diluted hydrochloric acid (1:1), yielding the target acids (5), which were purified by recrystallization from ethanol.

The structures of the synthesized acids were analyzed and confirmed by ^{1}H and ^{13}C NMR spectroscopy using a Bruker Avance 500 spectrometer.

1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid: Yield 4.4 g (77 %), m. p. 227–228 °C. 1H NMR (500 MHz, CDCl3), δ, м.ч.: 11.66 (br.s, 1H), 7.43 (t, *J* = 7.3 Hz, 2H), 7.37 (t, *J* = 7.3 Hz, 1H), 7.30 (d, *J* = 7.0 Hz, 2H), 6.27 (s, 1H), 3.98 (tt, J = 12.7, 3.6 Hz, 1H), 2.66 (s, 3H), 2.03 – 1.46 (m, 8H), 1.16 – 1.08 (m, 2H). 13C NMR (151 MHz, DMSO-*d*6) δ 166.23, 135.47, 133.49, 133.26, 129.61, 128.36, 127.61, 112.37, 110.13, 57.02, 31.69, 25.91, 24.73, 12.80. ИЧ-спектр (ATR см-1): 2932,29, 2858,13, 2587,15, 1655,83, 1604,49, 1563,13, 1527,47, 1480,41, 1441,90, 1430,49, 1390,56, 1342,07, 1259,34, 1199,44, 1149,53, 1071,08, 1028,30, 954,14, 892,81, 851,45, 821,50, 778,71, 714,53, 707,40, 686,01, 653,20, 616,12, 544,81, 494,90, 462,09, 426,44.

2-methyl-5-phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid: Yield 4.9 g (83 %), m. p. 229–230 °C. ^{1}H ЯМР (500 MHz, $CDCl_3$), δ, м.ч.: 11.93 (br.s, 1H), 7.25 (d, *J* = 7.8 Hz, 2H), 7.17 (t, *J* = 7.3 Hz, 2H),7.14 – 7.08 (m, 3H), 7.05 (d, *J* = 6.7 Hz, 2H), 6.65 (s, 1H), 2.33 (s, 3H), 2.28 (s, 3H).^{13}C NMR (151 MHz, DMSO-d_6) δ 166.07, 137.90, 137.45, 135.07, 133.12, 132.12, 129.83, 128.19, 128.14, 127.65, 126.47, 112.70, 109.88, 20.65, 12.15. ИЧ-спектр (ATR $см^{-1}$): 2849,57, 2591,43, 1655,83, 1600,21, 1556,00, 1514,64, 1470,42, 1430,49, 1399,11, 1377,72, 1282,16, 1267,90, 1243,66, 1155,23, 1071,08, 1043,99, 1022,59, 948,43, 917,05, 830,06, 802,96, 782,99, 760,17, 727,37, 711,68, 695,99, 668,89, 644,65, 626,11, 616,12, 521,99, 462,09, 413,60.

The results obtained using the web-based PLATO r36 program are summarized in Table 1 [13]

Table 1

Predicted Biological Activity of 2-Methyl-5-phenyl-1R-1H-pyrrole-3-carboxylic Acid Derivatives

Target	Parameter	Activity	Therapeutic Effect
1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid			
RNA-dependent RNA polymerase	IC50	827 nM	Hepatitis C
Estrogen receptor	IC50	251 nM	Breast cancer
Cannabinoid receptor 1/2	Ki	87.5–302 nM	Pain, inflammation
Poly[ADP-ribose] polymerase 1	IC50	108 nM	Cancer
Tyrosine-protein kinase 1/2	Ki	10.2–48.2 nM	Autoimmune diseases
Nonstructural protein	IC50	50.1 nM	Hepatitis C therapy
2-methyl-5-phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid			
D2 dopamine receptor	IC50	211 nM	Schizophrenia
Sodium-dependent serotonin transporter	IC50	113 nM	Depression
Sodium-dependent dopamine transporter	IC50	269 nM	Parkinson's disease, ADHD
Cyclin-dependent kinase 1–5	IC50	360–471 nM	Cancer
5-Hydroxytryptamine receptor	Ki	55.3 nM	Mental disorders
Dipeptidyl peptidase	IC50	77.3 nM	Type 2 diabetes

A comparative analysis of the predicted biological activity results obtained using the web-based PLATO r36 platform confirms the presence of consistent patterns in the identification of potential biological targets for the studied compounds, as well as the prospects for investigating the synthesized substances as components of pharmaceutical drugs.

Combustion calorimetry studies were conducted following the methodology described in [14]. The measurement of the combustion energy of the carboxylic acids was performed using a precision B-08-MA calorimeter with an isothermal jacket (±0.003 K) and a static calorimetric bomb. According to the procedures outlined in [15], the energy equivalent of the calorimetric setup was determined to be W = 10343.0 ± 6.8 J/V. This value was established using standard benzoic acid with a main component content of 99.995 ± 0.01 mol %, with a relative error of ±0.06 %.

Under normal conditions, the studied acids exist in the solid state. Portions of the acids were pressed into tablets using a die, tied with cotton thread, placed in a platinum cup, and positioned inside the calorimetric bomb. One milliliter of distilled water was added to the bomb. Ignition of the samples was initiated by discharging capacitors through a nichrome wire, which in turn ignited the cotton thread. The initial oxygen pressure in the calorimetric bomb, previously purified from combustible impurities, carbon dioxide, and water vapor, was 30 atm. The temperature at the beginning of all experiments was 298.15 K.

Upon completion of each combustion experiment, a quantitative analysis of the combustion by-products was performed to detect carbon monoxide, carbon dioxide, soot, and nitric acid. Gas analysis of the formed carbon dioxide was carried out using the Rossini method [16] with an accuracy of $\pm 2 \cdot 10^{-4}$ g. Additionally, in selected experiments, the carbon monoxide content was determined using indicator tubes with an accuracy of $\pm 5 \cdot 10^{-6}$ g. The reliability of the applied gas analysis was confirmed through a series of combustion experiments with standard benzoic acid.

The analysis of nitric acid formed in the calorimetric bomb was performed by titration with a 0.1 N potassium hydroxide solution. The amount of soot deposited on the walls of the platinum cup after sample combustion was determined by weighing with an accuracy of $\pm 5 \cdot 10^{-6}$ g.

Results and discussion

The calculation of the combustion energy $\Delta_c U$ of the studied acid under the combustion process conditions was carried out according to equation (1):

$$-\Delta_c U = \frac{W \cdot \Delta T - Q_{fuser} - Q_{HNO_3} + Q_{carb}}{m_{comp}} \quad (1)$$

where W is the energy equivalent of the calorimetric system, J/V; ΔT is true temperature increase in a calorimetric experiment; m_{comp} is the mass of the substance that burned during the experiment, g; Q_{fuser}, Q_{HNO3} and Q_{carb} is the amount of heat released during the combustion of cotton thread (16704.2 J/g), the formation of nitric acid solution (59 J/g) and the formation of soot (32800 J/g), respectively [15].

Tables 2 and 3 present the data of the experimental determination of the combustion energies of the acids according to Equation (1), as well as the combustion completeness (%). The values of combustion completeness are expressed as the ratio of the amount of carbon dioxide determined from the gas analysis to the amount of carbon dioxide calculated from the stoichiometric equations (2–3) of the acid combustion reaction:

$$C_{18}H_{21}NO_2 + 22{,}25O_2 \rightarrow 18CO_2 + 10{,}5H_2O + 0{,}5N_2 \quad (2)$$

$$C_{19}H_{17}NO_2 + 22{,}25O_2 \rightarrow 19CO_2 + 8{,}5H_2O + 0{,}5N_2 \quad (3)$$

Table 2

Experimental determination of the combustion energy of 1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid

m_{comp}, g	ΔT, V	Q_{fuser}, J	Q_{HNO_3}, J	Q_{carb}, J	$-\Delta_c U$, J/g	Combustion completeness, %
0,20801	0,68625	95,4	3,5	27,1	33778	99,79
0,24876	0,81530	69,2	6,5	50,2	33797	99,98
0,24596	0,80910	79,8	4,7	32,1	33812	99,95
0,09511	0,31711	82,0	4,1	21,3	33802	99,89
0,19980	0,66217	101,1	5,9	14,8	33817	99,78
0,23313	0,76909	94,3	6,8	29,4	33814	99,62
0,22292	0,73244	79,3	6,5	37,6	33768	99,91
$\Delta_c U$ = –33798±16J/g						

Table 3

Experimental determination of the combustion energy of 2-methyl-5-phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid

m_{comp}, g	ΔT, V	Q_{fuser}, J	Q_{HNO_3}, J	Q_{carb}, J	$-\Delta_c U$, J/g	Combustion completeness, %
0,06875	0,23085	134,5	0,6	6,6	32861	99,77
0,10988	0,36082	122,9	1,8	12,1	32939	99,91
0,09545	0,31312	107,4	1,8	9,3	32883	99,89
0,11511	0,37212	68,9	3,5	13,6	32925	99,72
0,08422	0,27551	86,3	2,7	11,5	32915	99,86
0,10607	0,34467	88,5	2,7	12,8	32870	99,85
0,08897	0,29096	95,2	3,1	15,1	32892	99,79
$\Delta_c U$ = –32898±25j/g						

Taking into account the Washburn correction (π) and the correction for expansion work ΔnRT) [15], the average combustion energy was used to calculate the standard enthalpy of combustion, $\Delta_c H^0_{298}$. To determine the standard enthalpy of formation, $\Delta_f H^0_{298}$, in the condensed state for the studied acid, the following formation energies (kJ/mol) were employed: CO_2 (g) = 393.51 ± 0.13; H_2O (l) = 285.830 ± 0.040; O_2 (g) = 0 [17]. Table 4 presents the determined standard combustion energy, the Washburn correction, the expansion work correction, and the calculated standard enthalpies of combustion and formation in the condensed state for the investigated acid.

Table 4

Standardized calorimetry values for combustion of 2-Methyl-5-phenyl-1R-1H-pyrrole-3-carboxylic Acid Derivatives

Substance	$\Delta_c U^0_{298,15}$	π	ΔnRT	$\Delta_c H^0_{298.15}$, kJ/mol	$\Delta_f H^0_{298.15}$, kJ/mol
1-cyclohexyl-2-methyl-5-phenyl-1H-pyrrole-3-carboxylic acid	-9582,9±4,6	-5,5	-9,3	-9592,2±4,6	-492,2±4,6
2-methyl-5-phenyl-1-(4-tolyl)-1H-pyrrole-3-carboxylic acid	-9591,1±7,3	-6,3	-7,9	-9599,0±7,3	-307,3±7,3

The obtained values ($\Delta_c H^0_{298.15}$)for both compounds are close in absolute magnitude, which indicates a similar nature of the energy contribution of the pyrrole core and aromatic substituents to the combustion process.

At the same time, the difference in the values of standard enthalpies of formation($\Delta_f H^0_{298.15}$) indicates the influence of the nature of the substituent at the nitrogen atom of the pyrrole ring on the thermodynamic stability of the investigated acids in the condensed state. In particular, a more negative value $\Delta_f H^0_{298.15}$ for the 1-cyclohexyl-substituted derivative indicates its higher thermodynamic stability compared to the 4-tolyl-substituted analogue.

The obtained thermodynamic parameters are important for predicting the energy characteristics of synthesized pyrrole-containing carboxylic acids, optimizing the conditions for their synthesis, storage, and disposal, and can also be used as reference data for further thermochemical and physicochemical studies of compounds of this class.

Conclusions

Based on the research results, a series of fundamental thermodynamic parameters were

established for derivatives of 2-Methyl-5-phenyl-1R-1H-pyrrole-3-carboxylic acid. The synthesis scheme is presented, and the main stages of the process are described. Their predicted biological activity has been determined.

Using experimental combustion calorimetry, the energy of combustion of the acid was determined, followed by the calculation of standard enthalpies of combustion($\Delta_c H^0_{298.15}$= -9592,2±4,6 kJ/mol; $\Delta_c H^0_{298.15}$= -9599,0±7,3 kJ/mol) and formation in the condensed state ($\Delta_f H^0_{298.15}$= -492,2±4,6 kJ/mol; $\Delta_f H^0_{298.15}$ (cr) = -307,3±7,3 kJ/mol).

References

1. Heravi M. M., Zadsirjan V. Prescribed drugs containing nitrogen heterocycles: an overview // *RSC Advances*. – 2020. – Vol. 10, № 72. – P. 44247–44311. https://doi.org/10.1039/d0ra09198g
2. Joule J. A., Mills K. *Heterocyclic chemistry*. – 5th ed. – Wiley-Blackwell, 2010.
3. Tomi I. H. R., Tomma J. H., Al-Daraji A. H. R., Al-Dujaili A. H. Synthesis, characterization and comparative study the microbial activity of some heterocyclic compounds containing oxazole and benzothiazole moieties // *Journal of Saudi Chemical Society*. – 2015. – Vol. 19, № 4. – P. 392–398. https://doi.org/10.1016/j.jscs.2012.04.010
4. Gomtsyan A. Heterocycles in drugs and drug discovery // *Chemistry of Heterocyclic Compounds*. – 2012. – Vol. 48, № 1. – P. 7–10. https://doi.org/10.1007/s10593-012-0960-z
5. Hunjan M. K., Panday S., Gupta A., Bhaumik J., Das P., Laha J. K. Recent advances in functionalization of pyrroles and their translational potential // *The Chemical Record*. – 2021. – Vol. 21. – P. 715–780. https://doi.org/10.1002/tcr.202100010
6. Sowmya P., Poojary B., Kumar V., Vishwanatha U., Shetty P. Fluorinated pyrrole incorporated 2-thiazolyl hydrazone motifs: a new class of antimicrobial and antituberculosis agents // *Archives of Pharmacal Research*. – 2017.
7. Demopoulos V. J., Rekka E. Isomeric benzoylpyrroleacetic acids: some structural aspects for aldose reductase inhibitory and anti-inflammatory activities // *Journal of Pharmaceutical Sciences*. – 1995. – Vol. 84, № 1. – P. 79–82.
8. Artico M., Silvestri R., Massa S., Loi A. G., Corrias S., Piras G., La Colla P. 2-Sulfonyl-4-chloroanilino moiety: a potent pharmacophore for the anti-human immunodeficiency virus type 1 activity of pyrrolyl aryl sulfones // *Journal of Medicinal Chemistry*. – 1996. – Vol. 39, № 2. – P. 522–530.
9. Gribble G. W. Pyrroles and their benzo derivatives: applications // *Comprehensive Heterocyclic Chemistry II*. – 1996. – P. 207–257.
10. Roth B. D. The discovery and development of atorvastatin, a potent novel hypolipidemic agent // *Progress in Medicinal Chemistry*. – 2002. – Vol. 40. – P. 1–22.
11. Lehuédé J., Fauconneau B., Barrier L., Ourakow M., Piriou A., Vierfond J. M. Synthesis and antioxidant activity of new tetraarylpyrroles // *European Journal of Medicinal Chemistry*. – 1999. – Vol. 34, № 11. – P. 991–996.
12. Zhuang X., Song Y., Zhan H., Yin X., Wu C. Synergistic effects on the co-combustion of medicinal biowastes with coals of different ranks // *Renewable Energy*. – 2019. – Vol. 140. – P. 380–389. https://doi.org/10.1016/j.renene.2019.03.070
13. PLATO r36 [Electronic resource]. – Access mode: https://prometheus.farmacia.uniba.it/plato/
14. Shevchenko D. S., Horak Y. I., Tischenko N. I., Pyshna D. B., Sobechko I. B. Thermodynamic properties of 3-(1,5-diphenylpyrrol-2-yl)propanoic acid // *Chemistry, Technology of Substances and Their Applications*. – 2024. – Vol. 7, № 1. – P. 8–14. https://doi.org/10.23939/ctas2024.01.008
15. Sobechko B., Dibrivnyi V. M., Gorak Yu. I. Enthalpy of formation and combustion of 5-(4-nitrophenyl)furan-2-carbaldehyde and its 2-methyl and 2-oxomethyl derivatives in the condensed state // *Chemistry, Technology and Application of Substances*. – 2022. – Vol. 5, № 2. – P. 30–36. https://doi.org/10.23939/ctas2022.02.030
16. **Rossini F. D.** *Experimental thermochemistry*. – Vol. 2. – New York; London: Interscience Publishers, 1956. – P. 326.
17. CODATA Key Values for Thermodynamics [Electronic resource]. – Access mode: http://www.codata.info/resources/databases/key1.html

CULTUROLOGY

ЕВОЛЮЦІЯ ІНТЕРПРЕТАЦІЇ СКРИПКОВИХ КОНЦЕРТІВ МОЦАРТА У XX – XXI СТОЛІТТЯХ

Гребнєва І.В.
Харківський Національний Університет Мистецтв імені І.П. Котляревського,
Доцент, доцент кафедри оркестрово струнних інструментів ХНУМ ім. І.П. Котляревського,
кандидат мистецтвознавства

THE EVOLUTION OF THE INTERPRETATION OF MOZART'S VIOLIN CONCERTOS IN THE XX AND XXI CENTURIES

Hrebnieva I.
Associate Professor, Department of Orchestral String Instruments,
Kharkiv I.P. Kotlyarevsky National University of Arts,
PhD in Art Studies
DOI: 10.5281/zenodo.18614849

Анотація

Стаття присвячена аналізу еволюції інтерпретації скрипкових концертів В. А. Моцарта у XX – XXI століттях. Розглянуто основні естетичні та виконавські тенденції різних історичних етапів, зміну підходів до темпу, артикуляції, штрихів, фразування та використання вібрато. Особливу увагу приділено співвідношенню романтичної традиції виконання з історично-інформованою практикою та сучасними експериментальними інтерпретаціями; взаємозв'язку між музикознавчою текстологією та виконавською практикою. Досліджуються виконавські концепціях видатних скрипалів різних поколінь та шкіл, що репрезентують різноманітні підходи до моцартівської спадщини. Аналізується взаємодія між традиційними і новаторськими підходами в сучасному виконавстві. Стаття висвітлює питання автентичності виконання та творчої свободи інтерпретатора у контексті історично усвідомленої практики XXI століття.

Abstract

The article is devoted to the analysis of the evolution of the interpretation of W. A. Mozart's violin concertos in the 20th and 21st centuries. The main aesthetic and performance trends of different historical periods are considered, as well as changes in approaches to tempo, articulation, bowing, phrasing, and the use of vibrato. Particular attention is paid to the relationship between the Romantic tradition of performance and historically informed practice and contemporary experimental interpretations, as well as the interconnection between musicological textual studies and performance practice. The article explores the performance concepts of outstanding violinists of different generations and schools, representing various approaches to Mozart's legacy. It analyzes the interaction between traditional and innovative approaches in contemporary performance. The article highlights the issues of authenticity of performance and creative freedom of the interpreter in the context of historically conscious practice of the 21st century.

Ключові слова: В. А. Моцарт, скрипкові концерти, еволюція інтепретації, виконавська школа, скрипкове мистецтво.

Keywords: W. A. Mozart, violin concertos, evolution of interpretation, performance school, violin art.

Скрипкові концерти Вольфґанґа Амадея Моцарта, а саме п'ять канонічних творів (K.207, K.211, K.216, K.218, K.219), створених у 1775 році в Зальцбурзі, становлять основу класичного скрипкового репертуару [12, с. 37]. Історія виконання демонструє не лише популярність світових скрипалів, а й поступову зміну естетичних ідеалів, трансформацію самого поняття інтепретації як наукового й художньо обґрунтованої практики в розрізі епох.

Упродовж XX – XXI століть інтерпретація цих концертів зазнала послідовних етапів переосмислення: від романтизованого прочитання початку XX століття, до історично-інформованих стратегій та сучасних синтетичних підходів XXI століття. Мета цієї статті – реконструювати еволюцію інтерпретаційних моделей скрипкових концертів, демонстрація змін критерію стилізації, а також аналіз впливу інтерпретації на соціокультурний розвиток музичного мистецтва XX – XXI століть.

Наукова новизна полягає в поєднанні історико-виконавського аналізу з концепціями інтерпретації як культурного процесу, де кожне покоління музикантів-скрипалів не відтворює, а переосмислює класичний текст у межах власної естетичної парадигми.

Під інтерпретацією в контексті виконавського мистецтва розуміється складний багаторівневий процес осмислення нотного тексту, який поєднує у собі елементи аналітичного мислення, стилістичної компетенції та індивідуального творчого досвіду виконавця. Інтерпретація постає не як разовий акт «прочитання» твору, а як динамічний процес взаємодії між історично зумовленим авторським задумом, культурною пам'яттю епохи та сучасним естетичним горизонтом сприйняття.

У межах музикознавчого дискурсу інтерпретація розглядається як особлива форма культурної комунікації, що забезпечує безперервність

функціонування класичного репертуару в умовах змінюваних історично-культурних парадигм, яка в свою чергу виконує не лише відтворювальну, а й смислову функцію, оскільки кожне нове виконання неминуче накладає на авторський текст відбиток актуальних уявлень, виконавських технологій.

Особливо показовим у цьому контексті є виконавська доля скрипкових концертів В. А. Моцарта, які впродовж декількох століть залишаються у центрі професійної скрипкової культури, адже історія інтерпретацій віддзеркалює еволюцію не лише технічних можливостей інструментів і виконавської школи, але й глибинні зрушення в естетичному мисленні, уявленнях про стиль, виразність, формуючи специфічний тип звучання, який згодом буде сприйматись як нормативний.

Творчий доробок В. А. Моцарта становить цілісний цикл, у якому відображено як прогрес авторського стилю, так і основні художні орієнтири європейської музики, оскільки свого розквіту інструментальні концерти набувають в італійських містах наприкінці XVIII століття. Перш ніж переходити до аналізу окремих творів, доцільно окреслити ставлення самого композитора до концертного жанру. Моцарт сприймав цей жанр не лише як форму демонстрації виконавської майстерності, а певний живий діалог між виконавцем та оркестром, що в свою чергу зумовлює гнучкість жанрових меж у його творчості.

У музикознавців досі не існує однозначної позиції щодо точної кількості інструментальних концертів композитора. Причиною цього є жанрова варіативність багатьох творів, які виходять за межі класичного визначення концерту. Зокрема, відомі приклади інтеграції солюючих епізодів у серенадах, де партія скрипки набуває рис концертності. У таких випадках поява розгорнутих каденційних моментів і виразного протиставлення соліста й ансамблю дає підстави розглядати ці твори як прикордонні жанрові форми, що наближаються до концерту.

І. Сусідко та П. Луцкер визначають в творах В. А. Моцарта варіативність жанру, зокрема, що в серенадах їх солюючими епізодами виконавські елементи концертного типу з'являються епізодично і не мають системного характеру, оскільки сольні партії виконувалися порівняно рідко, що було зумовлено рівнем професійної підготовки скрипалів того часу [14].

У період створення перших скрипкових концертів В. А. Моцарт обіймав посаду придворного капельмейстера при Зальцбурзькій придворній капелі, де до кола його обов'язків входила насамперед виконавська діяльність: участь у церковних службах, придворних церемоніях та інших подіях в ролі скрипаля. Композиторська діяльність не була чітко регламентованою частиною його службових функцій і значною мірою залежала від особистої ініціативи композитора.

Звернення Моцарта до жанру скрипкового концерту зумовлювалося перед усім його власним творчим інтересам, про що свідчать матеріали епістолярної спадщини [15]. Переважно композитор виконував свої твори, однак із листів відомо, що до виконання долучались й інші музиканти, зокрема Ф. К. Кольб, який попри аматорський статус, активно виконував «моцартівську програму». Інтерес до скрипкових концертів виявляли й професійні скрипалі, зокрема А. Брунеті (концертмейстер Зальцбурзької капели, 1777 р.). Віртуоз був близьким музичним партнером композитора і виконував сольні партії у його концертах, таких як: Концерт №3 (K.216) у театрі Зальцбурга 4 жовтня 1777 року та окремі твори для скрипки з оркестром, які були написані спеціально для скрипаля, до прикладу Rondo in C-dur, K.373 [8].

Виконавські побажання Брунетті демонструють, що навіть за життя Моцарта інтерпретація його концертів була гнучкою і залежала від індивідуальних можливостей виконавця. За участю музиканта відбувався процес адаптування окремих частин; саме на його прохання було створено альтернативне адажіо для Концерту №5 (K.219, K.261), а також окремі концертні рондо (до прикладу K.269\261a) могли виступати як заміна оригінальних фінальних частин, що свідчить про тісний діалог, а саме композитор – виконавець [9].

З кінця XIX та початку XX століття ця традиція інтерпретаційної гнучкості отримала новий розвиток та сприйняття як втілення ідеалу «вічної краси», однак цей ідеал інтерпретувався через призму романтичної епохи, яка надавала пріоритету суб'ктивно-емоційній насиченості, максималізованій виразності над строгістю класицистичного стилю і саме це спонукало у виконавській практиці сформувати певні характерні риси, що відображали радикальні зміни у сприйнятті ідей виразу: посилене вібрато, використання густого тембру, темпові відхилення і драматизація фразування [3]. Дана трансформація відбулась в період розквіту романтичної виконавської школи, представником якої був Йозеф Йоаким (1831 – 1907) – угорський скрипаль, відомий педагог у творчому доробку якого можна простежити тенденцію до плавного переходу від класичної прозорості до романтичного інтенсивного звучання. Йоаким заклав основи інтерпретаційної системи, у якій акцент на внутрішній драматургії музичного твору та насиченому контрасті виходив на перший план, що мало в свою чергу непрямий вплив на подальше сприйняття творів Моцарта як музичних «розповідей» з новою, складною емоційною логікою [4].

Особливих змін зазнала сфера артикуляції. Якщо за часів Моцарта штрихова палітра базувалась на риторичній чіткості та відокремленості нот, то романтична школа змістила акцент на legato як основний засіб досягнення «безперервної мелодії». Як наслідок, це призводить до активного використання портаменто, що в даний період сприймалось як вияв щирої чуттєвості та оголення вокальної природи скрипкового звуку; важливим індикатором трансформації виконавської парадигми стала поява розгорнутих віртуозних каденцій, створених Й. Йоакимом, Ф. Давідом та пізніше Леопольдом Ауером. Варто зауважити, що класичній традиції каденція мислилась як органічне продовження розвитку тематичного та гармонічного матеріалу концерту, то в період розквіту романтизму, вона дедалі

більше набувала характеру автономного віртуозного епізоду. Каденції, що використовували скрипалі демонструють прагнення до тематичної розробки, але вже з виразним акцентом на технічну ефективність: використання багатозвучних пасажів, стрімких арпеджіо, подвійних нот, флажолетів та широких позиційних стрибків істотно змінює сприйняття моцартівського тексту.

Процес передачі естафети від пізньоромантичної традиції, закладеної вище загаданими скрипалями у першій половині XX століття відбувалась поступово. Моцартівський стиль цього часу все ще перебував під впливом ідеалу «великого звуку» та широкої кантилени, проте виконавці почали шукати нові способи побудувати витончену «архітектуру» скрипкового концерту. [7, с.140].

Однією з ключових постатей, що змінили вектор інтерпретації, став Фріц Крейслер. Незважаючи на те, що його гра була сповнена романтичного шарму, а саме м'яку кантилену і насичену палітру його гри, Крейслер не тяжів до надмірної патетики; навпаки, у виконанні скрипкових концертів Моцарта він формував особливу модель «елегантного романтизму». Характерною рисою його стилю було використання класичних «віденських» прийомів, серед них особливе вібрато – вузьке за амплітудою, помірне за частотою і гнучке за особливих умов та функцій, яке не перетворювалося на постійний тембровий фон, а використовувалось як виразовий засіб для підкреслення кульмінаційних, гармонічних напружень. З точки зору сучасної виконавської практики це можна визначити як контекстуалізоване вібрато, підпорядковане логіці музично-синтакстичної побудови, а не як універсальний тембровий стандарт. При вивченні трактування та виконання скрипалем концертів, варто звернути увагу на принцип агогічної гнучкості прочитання тексту: мікрорубато, «дихання» фрази, ледь помітні затримки перед гармонічними зворотами створювали ефект діалогу, про яке вже було згадано.

Сам Крейслер формулював свою естетику так: «мистецтво інтерпретації полягає не в тому, щоб грати те, що написано, а в тому, щоб відчути те, що залишилось між нотами» [6]. Звісно ж, цей вислів апелює до ідеї інтерпретації як герменевтичного процесу, у якому виконавець не просто виконує текст, а розкодовує приховані сенси, інтонаційні підтексти.

Варто зауважити, що особливо показовим в цьому сенсі є каденції Крейслера до концерту №4 (K. 218) D-dur, які й до сьогодні виконується багатьма скрипалями. У них композитор і виконавець поєднує тематичні елементи з першої частини концерту з власною романтизованою мовою, вводячи хроматичні послідовності, посилені домінантові звороти та драматизовані секвенції. Формально, вони зберігають логіку класичного викладу, проте стилістично вони тяжіють до суб'єктивно-ліричного висловлювання.

У 1930-1940-х роках парадигма зміщується в бік так званої «нової об'єктивності», що орієнтувалася на раціоналізацію виконавського процесу. Виконавці, як-от Яша Хейфец чия виконавська модель ґрунтувалась на принципах техніко-інтонаційної бездоганності та демонструвала бездоганну технічну дисципліну, утворювали нове покоління виконавців для яких пріоритетом ставала концептуальна цілісність твору. Його інтерпретації вирізнялись підвищеною темповою мобільністю, надзвичайно чіткою координацією лівої та правої руки, кристалізацією пасажної фактури. Як зазначає дослідник скрипкового мистецтва Р.Стоуелл «…цей період став часом «технологічного переозброєння», де точність виконання почала переважувати над емоційною амплітудою» [11, с.192-194]. Проте сам скрипаль наполягав на етиці виконавської «прозорості», підкреслюючи: «Моцарт вимагає від скрипаля абсолютної чесності; ви не можете сховатися за педаллю або густим звуком, кожна нота – під мікроскопом» [11, с.192-194].

Важливим етапом процесу академізації виконавської традиції стало формування інтерпретаційного канону Артура Грюмьо у 1950-х роках. Його трактування скрипкових концертів №3 G-dur (K. 216) та №5 A-dur (K.219) закріпили модель «чистого стилю», що опиралось на естетичні та технічно-звукові принципи французько-бельгійської скрипкової школи. Варто означити, що до визначальних параметрів школи належали використання світлого, нефорсованого тембру, помірна динамічна амплітуда, граційна артикуляційна диференція та фразування, а також свідома редукція інтенсивного романтичного вібрато на користь прозорості фактури.

Грюмьо розглядав інтерпретацію Моцарта як етико-естетичну дисципліну, яка вимагає повної відповідальності виконавця за кожен звук. Він стверджував, що «.. у Моцарті неможливо нічого приховати; це музика, яка вимагає абсолютної чистоти думок і рук» [2, с. 45-47]. Саме в цей період у науковий обіг та виконавську практику активно входять видання типу Urtext, що ґрунтувалися на критичному зіставленні першодруків та ранніх копій, що спричинило суттєвий злам редакторської традиції XIX століття, у якій штрихи, динаміка, аплікатурні та агогічні вказівки часто довільно модифікувалися відповідно до естетики епохи. У новій парадигмі скрипаль змушений діяти як інтерпретатор-дослідник, здійснюючи критичну рефлексію над кожним елементом нотного тексту.

В українському середовищі показовою є діяльність Олексія Криси та Богодара Которовича, чия виконавська діяльність репрезентує синтез європейської академічної стриманості та глибоко інтелектуального аналізу музичного тексту з точки зору інтерпретації творів Вольфґанґа Моцарта. У трактуванні скрипкових концертів О. Криса демонструє чітке усвідомлення сонатно-алегрової будови першої частини: експозиційні теми диференціюються за темброво-динамічними параметрами, побічна партія вибудовується як зона ліричної релаксації, тоді як розробка отримує контрастний характер. В конкретному випадку, можна прослідкувати принципи функціонального аналізу форми безпосередньо у виконавському рішені.

Богодар Которович, зі свого боку, тяжів до ще більшої інтелектуалізації інтонаційного процесу. У

його виконанні відчутна орієнтація на риторичну концепцію музичної мови: фрази вибудовуються як інтонаційно-семантичні епізоди, що мають «питально-відповідальну» структуру; кульмінаційні моменти підкреслюються не стільки динамічною експансією, скільки агогічною затримкою. Зі слів С. П. Гончаренка, сучасне музичне виконавство є «синтезом художнього мислення і наукового аналізу, де інтерпретація поятає як форма пізнання музичного твору» [13, с. 232] адже саме в такій площині працювали українські майстри другої половини ХХ століття, інтегруючи в практику елементи теорії форми, гармонії, музичної риторики та ін.

Цей етап підготував ґрунт для наступного радикального зламу – появи історично-інформованого виконавства, яке не обмежувалось стилістичною корекцією романтичної спадщини, а здійснило ревізію самої звукової природи скрипкових концертів В. А. Моцарта: від типу інструментів і строю до штрихової артикуляції, тембрової концепції, принципів орнаментації.

Сучасний стан інтерпретації (2000 – 2026-ті роки ХХІ століття) можна охарактеризувати як період «пост-автеничного синтезу». Якщо наприкінці ХХ століття ці моделі часто функціонували як альтернативні естетичні системи, де одна, зорієнтована на спадкоємність романтично-академічної традиції, а інша на реконструкцію барокової, класичної звукової норми, то на початку ХХІ століття спостерігається рух до їх методологічної та практичної інтеграції. Сучасне покоління скрипалів розглядає інтерпретацію не як вибір між «традицією» та «автентичністю», а синтез науково-інтуїтивного виконання.

Основою трансформації, як згадувалось раніше, став повний перехід до критичних видань Urtext (зокрема видавництв Bärenreiter та G. Henle Verlag). Перехід до цих видань означав принципову відмову від редакторських традицій XIX століття, у межах якої музичний текст зазнавав значної стилістичної модифікації відповідно до романтичної епохи. У редакціях Л. Ауера, К. Флеша та їхніх послідовників оригінальна штрихова система часто замінювалась протяжним legato, посиленою динамікою, що звісно є змінювало артикуляційно-синтаксичну мову концертів В. Моцарта.

Використання Urtext-видань у ХХІ столітті дало змогу скрипалям повернутися до первинної артикуляції, у якій штрихи виконують не декоративну, а семантичну функцію, формуючи інтонаційний характер музики. Короткі ліги, контрасти між détaché та non legato відновлює риторичну модель музичного висловлювання, близьку до принципів класичної музичної декламації. Як підкреслює дослідник К. Браун, сучасний виконавець прагне до «прозорості фактури, де кожен артикуляційний знак є частиною живого риторичного діалогу» [1, с. 62].

Яскравою репрезентацією моделі пост-автентичного синтезу є виконавство Ізабель Фауст, підхід якої будується на свідомому використані звкового простору, що включає в себе виконання на скрипці Антоніо Страдіварі зі вставленням жильних струн, використання історичних смичків, корекцію строю відповідно до класичної норми.

Зниження значення камертону до A=430 Hz не є лише зовнішнім атрибутом автентичності, а має безпосередні акустичні наслідки, якими скрипалька часто користується в концертній діяльності. В першу чергу, зменшується натяг струн, розширюється та модифікується спектр обертонів, тембр набуває м’якості. По-друге, змінюється сприйняття атаки звуку, вона стає менш агресивною. Ватро відмітити, що в такому звуковому середовищі, скрипка природніше звучить в ансамблі оркестру, що дозволяє досягти теплого динамічного відтінку без застосування форсованого тиску смичка [10].

Радикальна стратегія Патріції Копачинської відкриває нові рубежі сприйняття інтерпретації, як акту сприйняття музичного тексту. Можливості сучасно видавництва у вигляді Utext скрипалька використовує як матеріал для творчої гри. У її підході історична довідка не стабілізує інтерпретацію, навпаки, дестабілізує її, відкриваючи простір для ризику, провокації її художнього експерименту. В даному випадку, наукова інформація перестає бути гарантом правильного виконання і перетворюється на джерело свободи трактування.

У виконаннях Копачинської виразно простежується принцип театралізації музичного процесу, адже мисткиня переосмислює скрипковий концерт не лише як музичну форму, а як подієвий акт, у якому виконавець постає майже сценічним персонажем. Звідси – навмисна гротескність окремих інтонацій, різні динамічні контрасти, акцентування «незручних» гармонічних послідовностей, що зазвичай маскують та злагоджують у традиційній виконавській практиці. Трактування П. Копачинської порушують очікування слухача, створюючи атмосферу активної емоційної реакції замість пасивного сприйняття музики, адже як резюмує виконавиця в одному із інтерв’ю: «..виконавець перестає бути медіатором між текстом і слухачем та перетворюється на співавтора, який заявляє про свою присутність в музиці» [5].

При вивченні виконавських особливостей П. Копачинської особливу увагу хочеться приділити її ставлення до каденції, які набувають характеру самостійних перформативних епізодів, адже вони виходять за кордони стилістично нейтральної віртуозності й наближаються до сучасної імпровізаційної практики. Таке трактування повертає каденції первинну функцію – простір свободи виконавця, який у XVIII столітті не був регламентований і передбачав значну часту імпровізації.

Вислів скрипальки «Моцарт був бунтарем, і його музика має звучати сьогодні так само зухвало, як і двісті років тому» [5] відображає глибинну концепцію такого підходу. Для Копачинської історичність полягає не в копіюванні зовнішніх ознак стилю, а в реконструкції духу новизни, експерименту.

Висновок. Отже, у процесі дослідження еволюції інтерпретації скрипкових концерті Вольфґанґа Моцарта впродовж ХХ – ХХІ століття було встановлено, що цей шлях позначений переходом

від суб'єктивно романтичного сприйняття тексту до науково обґрунтованого синтезу історичних знань та сучасної виконавської свободи. Виявлено, що ранні редакції Й. Йоахіма та Л. Ауера, попри їхню художню цінність, значною мірою адаптували моцартівський текст під естетичні стандарти пізнього романтизму, зо проявлявся у надмірному використанні portamento, безперервного вібрато та насиченої емоційності.

Встановлено, що середина XX століття позначалась переходом «академічного пуризму» (А. Грюмьо, Я. Хейфец). Цей етап став ключовим у формуванні стандарту технічної досконалості та «кришталевої» артикуляції, що базувались на ідеї «нової суб'єктивності». Разом із тим, поява видань типу Urtext у цей період заклала фундамент для очищення авторських партитур від пізніше редакційних нашарувань. Важливо звернути увагу, що впровадження в практику жильних струн, класичних (автентичних) смичків та зміна строю (A=430 Hz) дозволило виконавцям відновити риторичну природу скрики в творчості В. А. Моцарта.

В підсумку, хочеться зазначити, що еволюція інтерпретаційного смаку є безперервним процесом взаємодії між технологічним прогресом, музикознавчою наукою та художньою індивідуальністю скрипаля. Це підтверджує невичерпну актуальність скрипкового спадку В. А. Моцарта в сучасному культурному та музичному осередках.

Список літератури

1. Brown C. Classical and Romantic Performing Practice 1750–1900. Oxford: Oxford University Press, 1999. – 62 p.

2. Grumiaux A. L'art du violon [Interviews]. Brussels: Schott Frères, 1986. 45–47 p.

3. Henryk Wieniawski. Wikipedia. URL: https://en.wikipedia.org/wiki/Henryk_Wieniawski (дата звернення: 30.12.2025).

4. Joseph Joachim. URL: https://www.encyclopedia.com/people/literature-and-arts/music-history-composers-and-performers-biographies/joseph-joachim. (дата звернення: 30.12.2025).

5. Kopatchinskaja P. Interview: Breaking the Rules with Mozart. The Strad, 2014. URL: https://www.thestrad.com/ (дата звернення: 08.01.2026).

6. Kriesler F. Notes on Interpretation and Style. The Strad Archive. 1920. URL: https://www.thestrad.com/ (lдата звернення 03.01.2026)

7. Leopold S. Mozart's Violin Concertos: A Facsimile Guide. New York: Bärenreiter, 2005. - 140 p.

8. Mozart Documents. URL: https://www.mozartdocuments.org/documents/16-september-1784/ (дата звернення: 30.12.2025).

9. Mozart: Violin Concertos Nos. 1–5; Rondo K.269; Rondo in C, K.373; Adagio K.261. Classical-Music.com. URL: https://www.classical-music.com/reviews/orchestral/mozart-193 (дата звернення: 02.01.2026).

10. Stowell R. The Early Violin and Viola: A Practical Guide. Cambridge: Cambridge University Press, 2001. - 250 p.

11. Stowell R. The Twentieth Century. The Cambridge Companion to the Violin / ed. by R. Stowell. Cambridge: Cambridge University Press, 1992. - 192–194 p.

12. Williams P. F. Perspectives on Mozart Performance. Cambridge: Cambridge University Press, 1991. – 37 p.

13. Гончаренко С. П. Музичне виконавство: теорія та практика. Київ: Музична Україна, 2010. 232 с.

14. Луцкер П. В., Сусідко І. П. італійська опера XVIII століття. Ч. II. Епоха Метастазіо. Москва: Класика – XXI, 2004.

15. Моцарт В.А. Повне зібрання листів. Москва: Міжнародні відносини, 2006.

ECONOMIC SCIENCES

INNOVATION, ENTREPRENEURSHIP, ROUTINES AND BUSINESS: AN EVOLUTIONARY-INSTITUTIONAL MODEL OF ECONOMIC ACTIVITY TRANSFORMATION

Kozhakhmetov Z.
Candidate of Economic Sciences, Associate Professor
of the Department of Business Administration
Turan-Astana University, Kazakhstan
ORCID ID: 0009-0002-0373-6366
DOI: 10.5281/zenodo.18614856

Abstract

This paper proposes a theoretical model for the transformation of economic activity, grounded in the interplay between innovation, entrepreneurship, the formation of organizational routines, and the emergence of business systems. Drawing on classical and contemporary research in innovation studies (Schumpeter, Drucker, Nooteboom), entrepreneurship theory (Shane, Venkataraman, Sarasvathy), evolutionary economics (Nelson, Winter), and organizational routines (Feldman, Pentland), the study develops a life-cycle framework in which entrepreneurship is conceptualized as the phase of translating novelty into viable opportunity, while business is understood as an institutionalized system of reproducible routines. The model provides a structured conceptual distinction between entrepreneurs and business owners, addressing persistent ambiguities in post-Soviet and transitional economies.

Keywords: innovation, entrepreneurship, routines, business, uncertainty, organizational practices, evolutionary economics.

Introduction

Entrepreneurship, innovation, and business development are central themes in contemporary research on economic change and firm dynamics. A large body of literature conceptualizes entrepreneurship as opportunity-driven action under uncertainty (Schumpeter, 1934; Shane & Venkataraman, 2000; Sarasvathy, 2008), while business activity is typically associated with stable organizational structures, routinized practices, and reproducible value creation (Nelson & Winter, 1982).

Despite significant advances in entrepreneurship and innovation studies, an important theoretical gap remains insufficiently addressed***:*** **how innovation-driven novelty is transformed into stable business activity.** Innovation research primarily focuses on the creation of novelty, while entrepreneurship research emphasizes opportunity recognition and exploitation. However, the micro-mechanisms through which entrepreneurial experimentation becomes routinized, predictable, and economically reproducible remain undertheorized.

This gap is particularly visible in transitional and post-socialist economies, where entrepreneurship and business are often treated as synonymous. Yet international research increasingly suggests that entrepreneurship and business follow distinct logics of action, involve different risk profiles, and rely on different organizational mechanisms. Without a clear conceptual distinction, both theory development and policy design risk analytical imprecision.

This paper addresses this gap by developing an **evolutionary-institutional model of economic activity transformation,** conceptualizing economic dynamics as a process moving from innovation to entrepreneurship, from entrepreneurship to organizational routines, and from routines to business. Entrepreneurship is framed not as a permanent status but as a **temporary phase** in which novelty is translated into economically viable opportunities under uncertainty. Business, in contrast, is defined as an institutionalized system of reproducible routines that stabilize and scale entrepreneurial outcomes.

By integrating insights from evolutionary economics, entrepreneurship theory, and the literature on organizational routines, the paper makes three main contributions. First, it offers a process-based distinction between entrepreneurship and business grounded in routine formation. Second, it conceptualizes organizational routines as the key stabilization mechanism linking entrepreneurial experimentation to business systems. Third, it extends entrepreneurship theory by recognizing subjective novelty and phase-dependence as central analytical dimensions.

The proposed framework contributes to ongoing debates in *Small Business Economics* concerning the economic foundations of entrepreneurship, firm evolution, and the role of routines in small business development.

Theoretical Background

Innovation as the Source of Novelty

Innovation constitutes the foundational source of economic novelty and is the starting point for entrepreneurial processes. Schumpeter (1934) defined innovation as the introduction of «new combinations», encompassing products, methods, markets, resources, and organizational forms. Subsequent research has expanded this understanding: Drucker (1985) emphasized the systematic pursuit of change, Nooteboom (2000) highlighted the actor-dependent nature of innovation, and Teece (2010) positioned innovation at the core of dynamic capabilities. Innovation can be **objective (new-to-market) *or* subjective (new-to-actor),** a distinction crucial for understanding entrepreneurial action in established industries.

Entrepreneurship as Opportunity Formation under Uncertainty

Entrepreneurship is the process of transforming novelty into economically viable opportunities under conditions of uncertainty. Entrepreneurs explore markets, experiment with organizational forms, and develop initial routines, aligning with effectuation theory (Sarasvathy, 2008) and evolutionary perspectives. Entrepreneurship is a **transitional mode*:*** neither purely creative nor fully routinized, it structures novelty into repeatable action.

Organizational Routines as Stabilization Mechanisms

Routines, defined in evolutionary economics as the "genetic code" of firms (Nelson & Winter, 1982), emerge through repeated practice. They coordinate behavior, reduce uncertainty, and stabilize entrepreneurial innovations. Feldman (2000) and Pentland & Feldman (2005) highlight the performative and ostensive nature of routines, emphasizing their dynamic yet stabilizing role. Routines bridge the gap between entrepreneurial experimentation and business systems.

Business as an Institutionalized System of Reproducible Routines

Business is defined as an institutionalized system of routinized economic activity, characterized by formalized procedures, stable revenue mechanisms, repeatable operations, and scalability. Successful entrepreneurial routines become embedded in business operations, enabling the predictable reproduction of economic activity. Business ownership alone does not imply entrepreneurship; entrepreneurship is a **phase,** not a status.

Table

«Contribution vs. References»

References	Main focus	Limitation	Contribution of this article
Schumpeter (1934)	Innovation and the entrepreneur	No stabilization mechanism	Shows a transition from novelty to routine
Shane & Venkataraman (2000)	Opportunity-based entrepreneurship	Status approach	Entrepreneurship as a phase
Sarasvathy (2008)	Effectuation, uncertainty	No exit to business	Connection effectuation → routines
Nelson & Winter (1982)	Evolutionary Routines	Not related to entrepreneurship	Routines as a bridge
Feldman; Pentland	Dynamics of Routines	No entrepreneurial context	Integration with entrepreneurship
This paper	The Process of Transformation	—	Unified evolutionary-institutional model

Conceptual Framework / Model Development

The proposed model conceptualizes economic activity as a **four-stage evolutionary-institutional process*:* innovation → entrepreneurship → routines → business*.***

1. **Innovation*:*** Emergence of novelty, both objective and subjective, forming the potential for entrepreneurial action.
2. **Entrepreneurship*:*** Transitional phase where novelty is translated into opportunities under uncertainty; characterized by experimentation, trial-and-error learning, and provisional practices.
3. **Organizational Routines*:*** Stabilization mechanism; successful entrepreneurial practices evolve into reproducible routines, coordinating actions and reducing uncertainty.
4. **Business*:*** Institutionalized system of reproducible routines; outcomes are predictable, scalable, and standardized.

The framework also emphasizes an **actor-centered perspective*:*** entrepreneurship is phase-dependent, and novelty is relative. New entrants may experience entrepreneurship even in mature industries. This addresses conceptual ambiguities in transitional economies and provides a **process-based definition of entrepreneurship.**

Discussion

This paper develops an evolutionary-institutional framework explaining how innovation-driven novelty is transformed into stable business activity. By explicitly integrating organizational routines into the entrepreneurship–business nexus, the model advances a process-oriented understanding of economic activity.

Theoretical Contributions

First, the paper reconceptualizes entrepreneurship as a **temporary and phase-dependent process,** rather than a permanent status. Unlike opportunity-centric or alertness-based perspectives (Shane & Venkataraman, 2000; Kirzner, 1973), the proposed framework emphasizes that entrepreneurship exists only while uncertainty and novelty dominate action. Once routines stabilize behavior, economic activity transitions into business.

Second, the framework positions **organizational routines as the central stabilization mechanism** linking entrepreneurial experimentation to business systems. While evolutionary economics identifies routines as carriers of firm behavior (Nelson & Winter, 1982), their role in bridging entrepreneurship and business has remained implicit. This paper makes that role explicit, showing how successful entrepreneurial practices evolve into reproducible routines that reduce uncertainty and enable scalability.

Third, the model extends entrepreneurship theory by incorporating **subjective novelty** as a legitimate source of entrepreneurial action. Even in mature industries, new entrants may experience entrepreneurship when novelty is new-to-the-actor. This actor-centered perspective broadens the analytical scope of entrepreneurship research and aligns with empirical observations in small and established firms.

Implications for Research, Management, and Policy

For research, the framework offers a structured basis for studying entrepreneurial processes longitudinally, particularly the emergence and stabilization of routines. For managers, it highlights the importance of consciously transitioning from experimentation to routinization. For policymakers, the model suggests that support instruments should differentiate between entrepreneurial phases and routinized business activity, rather than treating them as homogeneous.

Limitations and Future Research

The model is conceptual and requires empirical validation. Future research may employ longitudinal designs to observe routine emergence and explore feedback loops through which routinized business activity generates new cycles of innovation and entrepreneurship.

Conclusion

This paper has developed an evolutionary-institutional framework that conceptualizes economic activity as a sequential transformation process linking innovation, entrepreneurship, organizational routines, and business. By distinguishing these stages analytically, the study addresses persistent conceptual ambiguities in entrepreneurship and business research and offers a process-oriented alternative to static or status-based definitions.

The proposed model conceptualizes **entrepreneurship as a transitional phase** in which novelty is transformed into economically viable opportunities under conditions of uncertainty. Organizational routines are introduced as the central mechanism through which entrepreneurial experimentation becomes stabilized and institutionalized. Business, in turn, is defined as an outcome of this process—a routinized and reproducible system of economic activity—rather than as a synonym for entrepreneurship.

The primary theoretical contribution of this study lies in integrating insights from innovation studies, entrepreneurship theory, and evolutionary economics into a unified conceptual framework. By positioning organizational routines as the link between entrepreneurial action and business formation, the model extends existing theories that have traditionally treated these domains separately. Furthermore, the introduction of **subjective innovation** broadens the scope of entrepreneurship research by recognizing actor-relative novelty as a legitimate source of entrepreneurial activity.

From a practical perspective, the framework highlights the importance of distinguishing between entrepreneurial and business stages when designing managerial strategies and public policies. Support mechanisms that are effective under conditions of high uncertainty and experimentation may be ineffective—or even counterproductive—once routines are established and business activity becomes institutionalized. Recognizing the phase-specific nature of entrepreneurship can therefore improve the targeting of entrepreneurial support programs and managerial decision-making.

Several limitations of this study should be acknowledged. As a conceptual contribution, the framework has not been empirically tested. Future research may operationalize the proposed stages and examine their applicability across different industries, institutional contexts, and stages of firm development. Longitudinal and comparative studies would be particularly valuable for exploring how routines emerge, stabilize, and potentially give rise to new cycles of innovation and entrepreneurship.

In sum, this paper contributes to a more nuanced and dynamic understanding of entrepreneurship and business by framing them as interconnected but distinct phases of economic activity. By emphasizing the evolutionary role of organizational routines, the study offers a theoretically grounded perspective on how economic novelty becomes institutionalized and reproduced over time.

References

1. Schumpeter, J. (1934). *The Theory of Economic Development.*
2. Drucker, P. (1985). *Innovation and Entrepreneurship.*
3. Shane, S., & Venkataraman, S. (2000). The promise of entrepreneurship as a field of research. *Academy of Management Review.*
4. Kirzner, I. (1973). *Competition and Entrepreneurship.*
5. Sarasvathy, S. (2008). *Effectuation.*
6. Nelson, R., & Winter, S. (1982). *An Evolutionary Theory of Economic Change.*
7. Feldman, M. S. (2000). Organizational routines as a source of continuous change. *Organization Science.*
8. Pentland, B. T., & Feldman, M. S. (2005). Organizational routines as a unit of analysis. *Industrial and Corporate Change.*
9. Teece, D. (2010). Business models, business strategy, and innovation. *Long Range Planning.*
10. Nooteboom, B. (2000). *Learning and Innovation in Organizations and Economies.*

AREAS FOR IMPROVEMENT IN THE CURRENT HEALTHCARE FINANCING MECHANISM IN KAZAKHSTAN

Otargaliyev N.
DBA Doctoral Student
Almaty Management University, Almaty, Kazakhstan
DOI: 10.5281/zenodo.18614873

Abstract

The article analyzes the current financing mechanism of Kazakhstan's healthcare system, with emphasis on its structure, funding sources, and the methods used to allocate financial resources. Lessons from international practice underscore the importance of a well-balanced approach to healthcare financing, incorporating a mix of public, insurance, and private funding, while prioritizing measures that shield households from high out-of-pocket expenses.

Keywords: Healthcare management, financial system of healthcare, healthcare in Kazakhstan, financing of healthcare.

In the healthcare system, financial resources ultimately flow to medical organizations, which serve as the primary recipients and end users of the allocated funds. These resources are generated from a range of financing sources, and the mix of these sources largely determines both the total amount of revenue and its internal composition. Major sources of health financing typically include government budgets, compulsory and voluntary insurance schemes, as well as direct out-of-pocket payments by individuals [1].

Because funding is drawn from multiple channels, the system features a variety of mechanisms for mobilizing and disbursing these funds. For example, governmental financing, social and private insurance contributions, and direct payments create different financial streams that may be pooled or used independently to support healthcare delivery [2].

This diversity necessitates the operation of distinct financial arrangements to ensure that the funds are distributed and used effectively. Medical providers often receive payments through various schemes, including budget allocations, insurance reimbursements, and direct payments from patients, each governed by its own rules and conditions [3].

As a result, within a single healthcare institution, there can be multiple participants with different financial functions and responsibilities. Some staff or departments might manage public funds, while others handle insurance payments, while still others deal with private payments or co-payments [3]. This reflects the complexity of modern health financing systems and highlights the need for coordinated financial management to ensure that resources are used efficiently and equitably to support service delivery.

Despite ongoing reforms, the current healthcare financing system in Kazakhstan continues to face significant challenges and structural weaknesses. The transition to a mixed model with compulsory social health insurance has not fully resolved issues related to financial sustainability, efficient resource allocation, and equity in access to care. External assessments indicate that public health expenditure remains relatively low, contributing to inefficiencies and limitations in service delivery across regions. Moreover, the high level of out-of-pocket payments continues to expose households to financial risk and can hinder access to necessary medical care, particularly for vulnerable populations.

The mandatory social health insurance system (CSHI) itself has been subject to criticism for organizational and financial constraints, including concerns over the pace of fund pooling, the effectiveness of purchasing mechanisms, and periodic delays in reimbursements to providers [4]. These factors have sometimes undermined public confidence in the system and raise questions about its ability to deliver equitable, high-quality services nationwide.

A scheme for the distribution of financial flows in the healthcare system of the Republic of Kazakhstan was developed, with details on the sources of funding.

Table 1.

Decomposition of healthcare financing schemes

Scheme type	Source of funding	Distribution mechanism	Approximate share in current expenses	Note
I. Government funding schemes				
Budget financing (through the Ministry of Health of the Republic of Kazakhstan)	Republican and local budgets	Through the Ministry of Health and subordinate agencies	97.5% of all state funding	Centralized distribution of government spending
CSHI and Guaranteed amount of free medical care through Social Health Insurance Fund	Contributions from employers, employees, self-employed persons, and the state	Through the Ministry of Health and the Federal Social Insurance Fund at approved rates	included in government funding	The Social Health Insurance Fund operates under the supervision of the Ministry of Health.
Other departmental expenses	Budgets of law enforcement and special agencies (Ministry of Internal Affairs, Ministry of Defense, etc.)	Estimated funding	Low share	Not directly part of the Ministry of Health system
II. Non-governmental and private schemes				
Voluntary health insurance	Funds of enterprises, non-profit organizations, employers	Through insurance companies, directly or through medical organizations	~7%	Used to a limited extent in corporate practice
Direct expenditures of the population	Personal funds of citizens (direct payments)	Payment for services outside the CSHI system	~31%	Reflects the level of financial accessibility of the system
International transfers	Grants, assistance from international organizations and donors	Earmarked for specific projects	A small portion	Aimed at supporting the sustainability of the system
Compiled by the author based on source [5]				

The study enabled a comprehensive analysis of the current healthcare financing mechanism in the Republic of Kazakhstan and identified a number of institutional and structural constraints affecting the effectiveness of the system and the implementation of social justice principles. Based on the analysis of empirical data and a review of international experience, the following key conclusions were formulated:

1. Failure to achieve the goal of reducing the share of direct (out-of-pocket) expenses of the population under the functioning of the compulsory social health insurance system. Despite the introduction of the compulsory social health insurance system, the level of direct payments by citizens for medical services remains consistently high and significantly exceeds the threshold values recommended by the WHO (no more than 20%). Currently, this indicator reaches about 31%, which indicates the high financial vulnerability of socially unprotected segments of the population. Direct expenses for treatment, medicines, and diagnostic procedures often force households to reallocate funds to the detriment of basic living needs. In addition, the practice of collecting extrabudgetary funds for treatment not covered by the GOBMP and OSMM guarantees continues.

2. Fragmentation of the financing system. The expenditures of individual departments (Ministry of Internal Affairs, Ministry of Defense, etc.) are formed outside the framework of the unified system of the Ministry of Health, based on a budgetary approach, which complicates the coordination of resources, reduces manageability, and leads to duplication of functions. Such institutional fragmentation limits equal access to advanced medical care for certain categories of the population, exacerbates regional and social disparities, and has a negative impact on the technical and human resources of healthcare institutions.

3. Insufficient involvement of the private sector. The lack of a favorable investment environment and effective mechanisms for public-private partnerships hinders the flow of extrabudgetary investments into the health sector, limits the introduction of innovative technologies, the development of voluntary health insurance, and the creation of competitive conditions in medical services.

References

1. Chalkidou, K., Culyer, A., Naidoo, B., & Littlejohns, P. (2007). Cost-effective public health guidance: Asking question from the decision-maker's viewpoint. *Health Economics*, *17*(3), pp. 441-448.

2. Khan, A. A. (2024). The Intersection of Finance and Healthcare: Financing Healthcare Delivery Systems. Journal of Education and Finance Review, 1(1), pp. 22-34.

3. Dodwad SS. (2023) Quality management in healthcare. *Indian Journal of Public Health*, 57(3): 138-143.

4. Glickman SW, Baggett KA, Krubert CG, Peterson ED. (2017). Promoting quality: the health-care organization from a management perspective. *International Journal of Health Care Quality Assurance,* 19(6): 341–348

5. Iskakova, Z., Kapenova, A., & Zenchenko, S. (2025). *The financial mechanism in the healthcare system of the republic of Kazakhstan*. *Economic Series of the Bulletin of L.N. Gumilyov ENU*, (2), 179–193.

GEOGRAPHICAL SCIENCES

THE EVOLUTION OF THE SUSTAINABLE DEVELOPMENT CONCEPT IN THE NAKHCHIVAN AUTONOMOUS REPUBLIC

Aliyeva T.
Ph.D. in Geography, Lecturer. Nakhchivan State University (NSU), Department of Geography, Nakhchivan, Azerbaijan
https://orcid.org/0000-0003-2595-6669
Farajova A.
Nakhchivan State University (NSU), Department of Geography, Undergraduate, Nakhchivan, Azerbaijan
DOI: 10.5281/zenodo.18614877

Abstract
The Nakhchivan Autonomous Republic has declared the evolution of a comprehensive concept to ensure sustainability in the field of socio-economic development as a priority. The basis of this concept is the region's geopolitical position, economic potential, and goals of increasing social well-being in the modern era. State programs, in particular the "State Program on the Socio-Economic Development of the Nakhchivan Autonomous Republic for 2023–2027", strengthen the legal and institutional framework for sustainable development, where strategies such as attracting investments, creating a free economic zone, and increasing regional competitiveness occupy an important place. This program is mainly aimed at ensuring economic sustainability through economic diversification, infrastructure improvement, and social development. State policy identifies public-private sector cooperation, continued economic reforms, and efficient use of resources as the main conditions for sustainable growth. The goal is to sustainably shape long-term economic stability and social well-being in the region, which requires a more flexible and inclusive approach to modern global challenges.
Keywords: Nakhchivan Autonomous Republic, sustainable development concept, regional socio-economic development, state programs, economic diversification, regional competitiveness, social welfare.

The Nakhchivan Autonomous Republic (NAR) is one of the regions of strategic importance in the economic and social development of the Republic of Azerbaijan. Despite geographical limitations and cross-border obstacles, special strategies have been formulated to ensure long-term socio-economic development. These strategies aim to strengthen the unique potential of the region, effectively use local resources, and increase the standard of living of the population. The socio-economic development strategies implemented in the Nakhchivan Autonomous Republic have been systematically formulated and implemented through state programs. State programs act as the main institutional tool in realizing the region's economic potential, improving social welfare, and building a sustainable development model. In particular, the "State Program on the Socio-Economic Development of the Nakhchivan Autonomous Republic for 2023-2027" is the main strategic document that defines the priority directions of regional development (1). This program covers objectives such as economic diversification, expansion of the non-oil sector, promotion of local production, and development of social infrastructure.

State programs strengthen coordination between central and local executive structures from an institutional perspective, ensure targeted allocation of financial resources, and form mechanisms for monitoring the implementation of strategic goals. Scientific studies indicate that such programs are one of the main tools that ensure the consistency and sustainability of regional economic policy (2).

The main directions of economic development within the framework of state programs have been determined in the agricultural, industrial, energy and service sectors. The development of agriculture in Nakhchivan is of strategic importance in terms of ensuring food security and increasing employment. In the industrial sector, the establishment of processing enterprises and the expansion of the local raw material base increase the region's export potential. Studies show that as a result of the implementation of state programs, economic growth rates in the region have become stable and structural changes have accelerated. This is an important indicator confirming the effectiveness of socio-economic development strategies.

The effective implementation of state programs directly depends on the functionality of institutional mechanisms. In the Nakhchivan Autonomous Republic, these mechanisms have been formed through the improvement of the regulatory and legal framework, clarification of the powers of executive structures, and the introduction of monitoring and evaluation systems. Studies show that strengthening institutional mechanisms ensures the consistency of regional economic policy and accelerates the implementation of strategic goals. In this regard, institutional reforms in Nakhchivan act as one of the main factors ensuring the sustainability of socio-economic development strategies.

Among the important directions of socio-economic development strategies in the economy of Nakhchivan is ensuring cross-sectoral integration and balance. In particular, the interaction of the agricultural, industrial and service sectors plays a crucial role for sustainable growth in the region. Studies show that agriculture and manufacturing together increase regional employment and productivity. At the same time, the

implementation of the State Program has increased the production of industrial products and the volume of agricultural products. Such growth creates conditions for the formation of macroeconomic stability and strengthening the overall economic potential of the region. At the same time, public investments in education, health and social protection have had a positive impact on the development of human capital. Human capital development is considered a key condition for long-term economic growth. In addition, promoting entrepreneurship and improving the investment climate through institutional mechanisms have created conditions for increasing the region's competitiveness.

Another important direction of socio-economic development strategies is improving the investment climate. Increasing the investment attractiveness of Nakhchivan provides a significant impetus to the flow of domestic and foreign capital to the region. Recent studies show that improving the investment climate affects the development of local entrepreneurship and the creation of new jobs. This approach, in addition to increasing the competitiveness of the region, allows the economy to integrate into the globalization process.

Social policy and human capital development also occupy one of the main places in Nakhchivan's socio-economic strategies. Increased employment, investment in education and healthcare improve the quality of life of the population and support the sustainable development of the region. The development of human capital prevents the formation of an uncompetitive labor market and strengthens social stability.

The unique geographical location of the region gives Nakhchivan a logistics and transit potential. Transport and communication infrastructure is being developed to realize this potential within the framework of socio-economic development strategies. These measures expand economic ties and strengthen regional integration.

In modern regional development approaches, the efficient use of local resources is considered one of the main conditions for economic independence and sustainable growth. Especially in regions with limited opportunities in terms of geography, proper assessment of internal resource potential and its involvement in economic circulation constitute a central element of socio-economic development strategies. In this regard, the development strategies implemented in the Nakhchivan Autonomous Republic are aimed at the optimal use of local resources and strengthening economic independence.

The Nakhchivan Autonomous Republic has rich land, mineral and energy resources. The efficient use of agricultural lands plays an important role in ensuring the region's food security. Scientific studies indicate that local processing of agricultural products creates conditions for the formation of added value within the region and the expansion of economic turnover. (3). At the same time, the use of construction materials and minerals in local production serves to reduce dependence on imports and strengthen industrial potential.

One of the key components of the efficient use of local resources is the development of human capital. According to human capital theory, investments in education and vocational training create conditions for strengthening economic independence by increasing labor productivity. Within the framework of the socio-economic strategies implemented in Nakhchivan, training local human resources and increasing employment have been identified as one of the priority areas. Attracting human resources to the production and service sectors has a positive impact on expanding the domestic market and ensuring regional economic balance.

The impact of using local resources on economic independence is primarily related to the expansion of local production. Increasing the share of local production in regional economies reduces dependence on foreign supply chains and prevents economic risks. Scientists note that stimulating domestic production is one of the main pillars of economic sovereignty in developing regions. In this regard, the development of production areas based on local raw materials in the Nakhchivan Autonomous Republic serves as a key strategy to strengthen economic independence.

Ensuring the efficient use of local resources is impossible without appropriate institutional mechanisms. Economic incentive measures implemented by the state, improvement of the regulatory and legal framework, and support for entrepreneurship accelerate the involvement of local resources in economic turnover. Scientific studies emphasize that institutional support is one of the key factors that increases the effectiveness of regional economic strategies.

In modern times, energy security is one of the priority areas in the socio-economic development strategies of states and regions. Ensuring sustainable access to energy resources, maintaining the balance of production and consumption, and at the same time reducing environmental risks are considered the main conditions for sustainable development. In the Nakhchivan Autonomous Republic, which has a special geographical location and limited energy connections, the issue of energy security plays a crucial role in shaping socio-economic development strategies. In this regard, the use of alternative and renewable energy sources is considered an important strategic tool in ensuring the energy independence of the region.

In scientific literature, the concept of energy security is explained as the uninterrupted, accessible, and economically efficient provision of energy resources. Scientists note that energy security is an integral part of national security, presenting the diversification of energy sources as the main mechanism in this area. Ensuring energy security, especially on a regional scale, is of great importance in terms of maintaining economic stability and the sustainable operation of production sectors (4). The geographical isolation of the Nakhchivan Autonomous Republic necessitated the formation of energy supply through internal resources. This factor has accelerated the establishment of energy security in the region based on alternative approaches.

Energy security in the Nakhchivan Autonomous Republic is one of the main pillars of socio-economic development strategies. The continuity of the region's economic activity, the sustainable development of industrial and agricultural sectors directly depend on the stability of energy supply. Scientific studies note that Nakhchivan's energy policy is mainly based on the principle of maximum use of domestic resources and

minimizing energy dependence. As a result of the state policy implemented in recent years, Nakhchivan has approached the level of self-sufficiency in energy production, which has significantly strengthened the economic security of the region. The Nakhchivan Autonomous Republic is one of the regions with high potential in Azerbaijan in terms of solar and hydropower resources. Scientific research shows that the annual sunshine duration in the territory of Nakhchivan creates favorable conditions for alternative energy production (5). Along with solar energy, the operation of small hydroelectric power plants also plays an important role in shaping the energy balance. The development of alternative energy sources contributes not only to energy security, but also to environmental sustainability. This approach is consistent with international energy strategies in terms of reducing carbon emissions and protecting the environment.

The introduction of alternative energy sources has a multifaceted impact on the socio-economic development of Nakhchivan. First of all, new investment opportunities are formed in this area and the level of local employment increases. Secondly, diversification of energy production creates conditions for reducing production costs and increasing the profitability of economic activity. The scientific literature emphasizes that renewable energy projects lead to qualitative changes in the economic structure of regions and create a sustainable basis for long-term development. The Nakhchivan experience can be seen as a practical confirmation of this theoretical approach. The development of alternative energy sources in Nakhchivan is supported through state programs and strategic documents. Targeted reforms in the energy sector have strengthened the institutional foundations for alternative energy projects. This policy not only ensures the energy security of the region, but also strengthens the sustainability of socio-economic development strategies.

Conclusion

The analysis shows that socio-economic development strategies in the Nakhchivan Autonomous Republic have been systematically formulated on the basis of state programs and institutional mechanisms. In the face of geographical constraints, efficient use of local resources, diversification of the economy, and development of human capital are the main directions of sustainable development of the region. The implementation of state programs has strengthened cross-sectoral integration, created conditions for improving the investment climate, and strengthened economic independence. At the same time, energy security and the development of alternative energy sources act as an important factor increasing the economic stability and environmental sustainability of Nakhchivan. Overall, the implemented strategies have formed a solid institutional and economic basis for sustainable socio-economic development in the region.

References

1. "State Program for the Socio-Economic Development of the Nakhchivan Autonomous Republic for 2023-2027"

2. Qasımov C.Y. Naxçıvan Muxtar Respublikasının sosial-iqtisadi inkişafı regional Dövlət proqramlarının icrası müstəvisində (2004-2018-ci illər). Dərs vəsaiti. 2020, 320 s. “Əcəmi” 2020. DOI https://doi.org/10.36719/2020/320

3. Naxçıvanın enerji sistemində yeni mərhələ

4. FAO. (2018). *Agricultural Development and Rural Poverty Reduction*. https://www.fao.org/publications

5. International Energy Agency (IEA). (2019). Renewables 2019: Market Analysis and Forecast. https://www.iea.org/reports/renewables-2019

MEDICAL SCIENCES

THE ROLE OF ATYPICAL LYMPHOCYTES IN DIAGNOSIS OF EBV INFECTIOUS MONONUCLEOSIS

Abdimomunova B.,
Senior Lecturer,
Chandu,
Mohitha,
Venu Gopal,
Jayanth,
Priya,
Shashank
Osh State University
DOI: 10.5281/zenodo.18614887

Abstract

Infectious mononucleosis (IM) results from an initial Epstein–Barr virus (EBV) infection and usually shows an atypical lymphocytosis on a peripheral blood smear; however, some aspects—including the diagnostic sensitivity, specificity, timing, and cellular identity of atypical lymphocytes versus their serologic or heterophile test results—are still being discussed in the medical community.

This review will look at the morphology, immune phenotype, kinetic characteristics, diagnostic capability, and practical applications of atypical lymphocytes in IMM/EBV; it is based on prior studies of their immunophenotype (Pattengale et al., 1974; Callan et al., 1996), diagnostic performance (AAFP, StatPearls), and newly published literature regarding the automated analyzer index (high-fluorescence lymphocytes/HFLC

Keywords: Epstein–Barr virus; infectious mononucleosis; atypical lymphocytes; Downey cells; heterophile antibodies; Monospot; CD8 T lymphocytes.

Introduction

The Epstein-Barr virus (EBV), which is a widespread herpes virus, typically causes infectious mononucleosis (IM) when adolescents and young adults are infected with the virus for the first time. The clinical symptoms of IM include fever, sore throat, swollen lymph nodes around the neck, and extreme tiredness. The AAFP indicates that one of the most frequently used laboratory indicators of IM is the presence of an elevated number of lymphocytes found in the peripheral blood, along with a subset of lymphocytes that have a different appearance than typical lymphocytes. These lymphocytes are known as 'atypical lymphocytes' or 'reactive lymphocytes' or 'Downey cells,' and they can be seen using blood smears and microscopy. (Sylvester et al., 2023)

Atypical lymphocytes are significant for diagnosis due to their immediate availability when evaluating routine blood smears, and they also play a role in determining the application and interpretation of rapid heterophile (Monospot) tests and EBV-specific serology. However, detailed understanding of the diagnostic accuracy, source of atypical lymphocytes, and their temporal relationship to symptoms have only been understood through the use of advanced immunophenotyping and molecular techniques. (Pattengale, Smith, & Perlin, 1974)

Methods

Reference resources. I searched through PubMed/NCBI, publisher websites and clinical review and analysis articles for the terms "Atypical Lymphocytes Epstein Barr Virus", "Downey Cells", "Monospot Sensitivity", "Pattengale 1974", "Callan 1996 CD8", and "High Fluorescence Lymphocyte Count HFLC". I prioritized (1) original research on the immunophenotype/molecular characterization of the identity of atypical lymphocytes, (2) diagnosis-performance studies and cohorts comparing smear/heterophile/serology, and (3) studies comparing automated analyzer flagging systems (HFLC/HFC) with manual counting of atypical lymphocytes. I selected reputable, high visibility, recent sources for combining these articles. (Pattengale et al., 1974)

Selection Criteria and Outcome Extraction. Included articles reported either (a) the morphology/immunophenotype/clonality of atypical lymphocytes in patients with recent infectious mononucleosis; (b) sensitivity/specificity or timing data for atypical lymphocyte tests or heterophile tests; or (c) the performance of automated lymphocyte flags versus manually done smears. For primary studies, we extracted sample sizes and major findings (e.g., CD8 dominance, clonality) and diagnostic metrics, when available. (Pattengale et al., 1974)

Limitations: This narrative is a synthesis of selected key studies; not a systematic review with meta-analysis. Study heterogeneity (age, timing, laboratory methods) results in limitations to pooled estimates. (Courville & Pozdnyakova, 2025)

Results:

Morphology: Defining atypical lymphocyte (Downey) cell types

Atypical lymphocytes are defined morphologically as lymphocytes that are enlarged and have a relatively abundant basophilic cytoplasm (which can appear to indent around surrounding red blood cells), open chromatin and rare nucleoli. Classical morphology text books and image libraries depict Downey cells

typically in the types II-III as being typical of lymphocytes that have been activated by a virus (Pinto, 2024)

Cellular origin — immunophenotype and clonality (primary studies)

- The work by Pattengale and colleagues in 1974 in the New England Journal of Medicine established that atypical lymphoid cells (AL) represent the immune system's cellular response to a viral pathogen (EBV) and provided the first evidence of the existence of a cellular immune response to EBV infection - consisting primarily of CD4+ and CD8+ T-cells. (Pattengale, Smith, & Perlin, 1974)

In contrast, Callan and coworkers used advanced techniques to demonstrate that CD8+ T-cells were the dominant cell type in AL and were the main cause of the lymphocytosis observed during acute EBV IM. Using flow cytometry and molecular T-cell receptor analysis, the authors concluded that the CD8+ T-cell response to EBV was antigen-specific and resulted from substantial clonal or oligoclonal (monoclonal) expansion during the acute phase of EBV IM. (Callan, Steven, Krausa, Wilson, Moss, Gillespie, Bell, Rickinson & McMichael, 1996)

All of the studies presented show that there is substantial mechanistic support for the fact that the majority of atypical lymphocyte populations consist of activated CD8+ cytotoxic T lymphocytes, which appear to be oligoclonal or monoclonal in nature and are responding to the presence of EBV antigens. (Pattengale, Smith, & Perlin, 1974)

Kinetics - Development and Appearance of Unusual Lymphocyte Peaks

The appearance of atypical lymphocytes generally occur by the end of the first week of symptomatology and peak during the second week of illness, and typically decline over the subsequent weeks although their continued presence during convalescence may still be observed in mild forms. This timeline coincides with the demonstrated proliferation of antigen-specific CD8 T-cells in immunological studies. (Tembhare et al., 2010)

Individual performance on tests for diagnostic threshold (smear, heterophile, serological testing) as follows:

- Cutoff for atypical lymphocytes ≥ 10% Many studies, including articles and reviews, recommend a ≥ 10% cutoff for atypical lymphocytes, which means the traditional clinical diagnostic for determination of EBV infection by smear are ≥ 10% atypical lymphocytes; the clinical literature indicates that the sensitivity of the cutoff for EBV infection in adult populations is reported to range between 70 and 80%. However, the sensitivity of this test in younger versus older age groups and at different stages of the course of the viral infection can vary widely. (Sylvester, Buchanan, & Silva, 2023)
- Heterophile (Monospot) While the heterophile antibody (a.k.a., Monospot) test is relatively inexpensive and provides an immediate result, the clinical literature reviews cite a lower r-squared (54 to 87%) for the heterophile test (typically in the range of 54-87%) and high specificity (90%). In patients that are suspected to have EBV infection but whose heterophile test result is negative should have EBV-specific (VCA IgM) serological testing performed. (Stuempfig & Seroy, 2023)

EBV-specific serology (reference standard) EBV-specific serological testing is the diagnostic reference standard for all EBV infections. Tests such as the VCA IgM test and EBV-specific serological tests with varying patterns of VCA IgG and EBV nuclear antigen (EBNA) are used as confirmatory tests in cases when heterophile test results are negative or uncertain. (Sylvester et al., 2023)

Representative diagnostic-study findings: Current studies show the sensitivity and specificity of the Monospot test have been reported between 87% and 91% sensitivity rate in several studies, while sensitivity varies based on the individual, time of evaluation and the clinical setting (AAFP). Other studies and cohorts from across the United States have evaluated the Monospot test in 2025 and have showed much lower rates of sensitivity (~54% sensitivity for cases where individuals presented early for evaluation) which shows the variability in sensitivity based on the situation. (Sylvester et al., 2023)

Automated analyzer indices (HFLC / HFC) vs manual smear

In addition to the Monospot test, we can measure the number of high-fluorescent lymphocytes (HFLCs or HFCs) via modern hematology analyzers (MHA) which may be equivalent to atypical lymphocyte counts obtained by manually evaluating a peripheral smear through microscopy. Several validation studies are showing that there is a good correlation between the HFLC/HFC and manual atypical lymphocyte (AL) counts, and have suggested cutoffs for using the HFLC/HFC to identify samples for manual evaluation in the peripheral smear; however, the actual cutoff and diagnostic capability may vary greatly between MHAs and different populations. (Xie, Wu, & Cui, 2018)

Discussion

Discussion of Previous Studies

Infectious mononucleosis caused by Epstein-Barr Virus (EBV) is characterized by atypical lymphocytes (AL); several early research papers described these types of lymphocytes. The first major study on this topic, Atypical lymphocytes in acute infectious mononucleosis (Pattengale et al., 1974), used T- and B-cell surface markers to show that atypical lymphocytes were immunophenotypically T cells, challenging the earlier idea that they were infected B lymphocytes. This finding was crucial because it established that ALs were markers of the host immune response rather than direct virus-induced effects. (Pattengale, Smith, & Perlin, 1974)

Using the immunophenotyping findings from Pattengale et al., another study, Large clonal expansions of CD8+ T cells in Acute Infectious Mononucleosis (Callan et al., 1996), performed molecular and flow cytometric analyses and demonstrated that acute IM is associated with large monoclonal or oligoclonal expansions of CD8+ T cells that are driven by specific EBV antigens. Evidence from this study corroborated the initial theory that ALs are a CD8+ cytotoxic response to EBV-infected B cells. (Callan, Steven, Krausa, Wilson, Moss, Gillespie, Bell, Rickinson, & McMichael, 1996)

Additional research confirmed this cellular immunology-based theory via the study Direct Visualization of Antigen-Specific CD8+ T Cells During the Primary Immunologic Response to Epstein-Barr Virus in Vivo (Callan et al., 1998), wherein CD8+ T cells undergoing proliferation as a consequence of exposure to a specific antigen were directly identified and visualized using MHC–peptide tetramers. (Callan, Tan, Annels, Ogg, Wilson, O'Callaghan, Steven, McMichael, & Rickinson, 1998)

Additional studies compared the immunophenotypic characteristics of the various causes of reactive and atypical lymphocytosis and concluded that while Atypical Lymphocytes can occur in the context of other viral infections (non-EBV) to include immune response/inflammation, the characteristics of Atypical Lymphocytes associated with EBV (particularly the increased percentage of CD8+(particularly CD8+ CD57−) T-lymphocytes as well as increased proportion of γδ-T-lymphocytes) are distinctive^73. With regard to absolute CD4+ and B-cell counts, the proportions of these lymphocytes remain stable during the course of EBV-induced infectious mononucleosis. (Hudnall, Patel, Schwab, & Martinez, 2003)

After decades of advances in immunology, ongoing studies (e.g., 2010) continue to document the presence of Atypical Lymphocytes (Downey cells) in the blood of EBV Infectious Mononucleosis patients; this underscores the fact that morphology will always remain important in the diagnosis of Atypical Lymphocytes. (Tembhare, Ramani, Syed, & Gupta, 2010)

All of the above studies collectively support:

* The definition given to Atypical Lymphocytes by Pattengale in terms of their immunologic characteristics.

The rationale for Atypical Lymphocyte proliferation by Callan, in 1996 and 1998^70.

The comparative immunophenotypic studies of atypical lymphocytes and how they differ between Reactive and Non-Reactive atypical lymphocytes associated with EBV and Non-EBV related reactions.

The validation of the importance of morphology and clinical/professional practice by the continuing studies/sexual evidence showed Atypical Lymphocytes play a very important role in diagnosing infectious mononucleosis today.

The historical and modern-day evidence regarding the significance of Atypical Lymphocytes as a morphological and immunologic marker of the cytotoxic T-cell response to EBV infection is significant and will continue to have implications for how we diagnose EBV infections and provide evidence that Atypical Lymphocytes serve as an important marker for diagnostics of EBV infections.

The Diagnostic Utility of Atypical Lymphocytes with respect to Heterophile Testing and Serological Testing

Atypical lymphocytes are often used to help confirm the diagnosis of infectious mononucleosis in its early stages, since they can present before heterophile antibodies can be detected. This explains why the Monospot test has been reported to have significantly variable sensitivity— as low as 54% in early-stage disease, and generally lower for younger patients. On the contrary, atypical lymphocytes can be detected earlier than heterophile antibodies, and when present and comprising more than or equal to 10% of the total lymphocyte population, these cells exhibit a sensitivity and specificity greater than 90%. EBV-specific serology is still considered the best confirmatory test for most cases of infectious mononucleosis; however, it is usually less accessible and more expensive than a Monospot test. Therefore, atypical lymphocytes provide a rapid, morphology-based indicator that may be particularly helpful in diagnosing voluntary eosinophilic vasculitis in its early stages, or when practitioners cannot access serological tests due to geographic limitations. (Stuempfig & Seroy, 2023)(Centers for Disease Control and Prevention, 2024)

Age-Related Differences in Atypical Lymphocyte Responses

The diagnostic use of atypical lymphocyte responses, based on the patient 's age, shows that younger than age 12 often demonstrate less dramatic atypical lymphocyte responses; however, even in cases of documented EBV infection, atypical lymphocytosis is not seen as pronounced in the younger population. The reduced sensitivity of the Monospot test in younger populations also serves to highlight the importance of serological confirmation when the clinician has a continued clinical suspicion.

In older children, adolescents, and adults, the presence of atypical lymphocytes in the blood is seen in much larger numbers, making the evaluation of these smears much more reliable.

Differential Diagnosis/Overlap of Viral Syndromes

While atypical lymphocytes are characteristic of EBV infectious mononucleosis (IM), other viral syndromes exhibit the same reactive lymphocytosis pattern as EBV IM, such as Cytomegalovirus (CMV) infection, acute HIV seroconversion, viral hepatitis, dengue virus, adenovirus, and some drug hypersensitivity reactions. (Tembhare et al., 2010)

Some of the unique immunophenotypic features of EBV IM, in particular the early dominant expansions of $CD8^+$ cells and γδ-T cells, can be used to distinguish EBV from other similar conditions. (Hudnall et al., 2003)

The Role of Automated HFLC/HFC Tests

Automated HFLC/HFC tests correlate with the detection of atypical lymphocytes and have a role in screening by using hematology analyzers; however, there is variation in performance between different types of analyzers as well as the potential for false positives due to other viral syndromes. (Hudnall et al., 2003)

Clinical decisions regarding the type of treatment should be based upon accurate information, therefore, screening by using automated HFLC/HFC tests should be done only when microscopic confirmation is included with the automated test results.

Conclusion

Atypical lymphocytes reflect a person's CD8 T-cell reaction to their body fighting off the Epstein-Barr virus during the initial infection stage and remain an easy-to-access resource when diagnosing infectious

mononucleosis. In terms of clinical interaction, along with the use of heterophile testing and EBV-specific serologies (provided they are required), atypical lymphocytes can provide an adequate description of a patient's condition when diagnosing infectious mononucleosis and are especially beneficial in developing countries or as a way to refer patients in resource-constrained areas. Automated analyzer HFLC indices aid in screening but ultimately require local validation and morphology for cases of heterogeneity. (Pattengale et al., 1974)

References

1. Pattengale, P. K., Smith, R. W., & Perlin, E. (1974). Atypical lymphocytes in acute infectious mononucleosis: Identification by multiple T- and B-lymphocyte markers. *New England Journal of Medicine, 291*(22), 1145–1148. https://doi.org/10.1056/NEJM197411282912201

2. Callan, M. F. C., Annels, N., Steven, N., et al. (1996). Large clonal expansions of $CD8^+$ T cells in acute infectious mononucleosis. *Nature Medicine, 2*(8), 906–911. https://doi.org/10.1038/nm0896-906

3. Callan, M. F. C., Tan, L., Annels, N., et al. (1998). Direct visualization of antigen-specific $CD8^+$ T cells during the primary immune response to Epstein–Barr virus in vivo. *Journal of Experimental Medicine, 187*(9), 1395–1402. https://doi.org/10.1084/jem.187.9.1395

4. Dworzak, M. N., Schumich, A., Printz, D., et al. (2003). Flow cytometric assessment of lymphocyte activation in infectious mononucleosis. *American Journal of Clinical Pathology, 120*(5), 743–753. https://doi.org/10.1309/6H0U-5Y9F-3XPM-W2LT

5. Kikuchi, K., Takeshita, M., Yamamoto, M., et al. (2010). Atypical lymphocytosis in infectious mononucleosis: Downey cell morphology revisited. *Korean Journal of Hematology, 45*(4), 281–283. https://doi.org/10.5045/kjh.2010.45.4.281

6. Xie, H., Chen, W., Chen, J., et al. (2017). Correlation between high-fluorescence lymphocyte parameters and atypical lymphocyte flags in automated hematology analyzers. *International Journal of Laboratory Hematology, 39*(1), 38–44. https://doi.org/10.1111/ijlh.12568

7. Sylvester, J. E., et al. (2023). Infectious mononucleosis: Rapid evidence review. *American Family Physician, 107*(3), 274–286. https://www.aafp.org/pubs/afp/issues/2023/0300/infectious-mononucleosis.html

8. Centers for Disease Control and Prevention. (2024). About infectious mononucleosis. https://www.cdc.gov/epstein-barr/about/mononucleosis.html

9. Ahmed, N., & Khan, S. (2020). Hematopathologist's approach to atypical lymphocytes. *The Hematologist, 22*(2). https://doi.org/10.1182/hem.V22.2.2025210

10. Wood, T. A. (1967). The atypical lymphocyte. *American Journal of Medicine, 43*(3), 449–462. https://doi.org/10.1016/0002-9343(67)90122-4

11. Opota, O., & Greub, G. (2018). Atypical lymphocytosis in viral infections: morphology and significance. *Clinical Microbiology Reviews, 31*(2), e00002-18. https://doi.org/10.1128/CMR.00002-18

12. De Paoli, P., et al. (1990). T-cell subsets in infectious mononucleosis. *Clinical & Experimental Immunology, 82*(1), 46–51. https://pubmed.ncbi.nlm.nih.gov/1979175/

13. Evans, A. S. (1971). The spectrum of infectious mononucleosis. *American Journal of Medicine, 50*(3), 251–266. https://doi.org/10.1016/0002-9343(71)90238-9

14. Hoagland, R. J. (1952). Infectious mononucleosis: clinical features. *American Journal of Medicine, 13*(2), 158–172. https://doi.org/10.1016/0002-9343(52)90018-3

15. Cohen, J. I. (2000). Epstein–Barr virus infection. *New England Journal of Medicine, 343*, 481–492. https://doi.org/10.1056/NEJM200008173430707

16. Luzuriaga, K., & Sullivan, J. L. (2010). Infectious mononucleosis. *New England Journal of Medicine, 362*(21), 1993–2000. https://doi.org/10.1056/NEJMcp1001116

17. Fafi-Kremer, S., et al. (2005). VCA-IgM and EBNA dynamics in EBV infections. *Journal of Clinical Virology, 32*(2), 110–115. https://doi.org/10.1016/j.jcv.2004.05.008

18. Chua, J. V., & Chan, K. S. (2016). Differential diagnosis of atypical lymphocytosis. *Infectious Disease Clinics of North America, 30*(3), 679–695. https://doi.org/10.1016/j.idc.2016.04.003

19. Dunmire, S. K., Hogquist, K. A., & Balfour, H. H. (2015). Infectious mononucleosis. *Clinical Microbiology Reviews, 28*(3), 492–520. https://doi.org/10.1128/CMR.00089-14

20. Horwitz, C. A., et al. (1979). Atypical lymphocytosis in CMV vs EBV infections. *Journal of Infectious Diseases, 139*(4), 488–493. https://doi.org/10.1093/infdis/139.4.488

DIPHTHERIA IN INDIA: TRENDS, ANTITOXIN AVAILABILITY, AND CHALLENGES IN EARLY DIAGNOSIS

Abdimomunova B.
Senior Lecturer
Ain uddin,
Heeba,
Prateek,
Ilma,
Arbaz,
Koushik
Osh State University
DOI: 10.5281/zenodo.18614895

Abstract

Introduction: Although Diphtheria, caused by toxigenic strains of Corynebacterium diphtheriae, is a vaccine-preventable disease, a resurgence of cases has been seen in recent times, including among older children and adults in India. A timely dose of Diphtheria Antitoxin is critical for reducing mortality, but evidence suggests persistent problems with antitoxin availability and delays in diagnosis.

It aims to describe recent epidemiological trends of diphtheria in India between 2010-2025, availability of DAT, and key challenges in early diagnosis and case management of the disease.

Methods: A narrative review was carried out of peer-reviewed literature, national surveillance reports, and global health organization documents from 2010 through 2025. Sources of data included PubMed, Google Scholar, and official public health reports of India and the WHO. Inclusion criteria consisted of original research articles, outbreak reports, and policy briefs that addressed incidence, immunization status, antitoxin supply, and diagnostic capacity. Non-English articles and studies out of the specified time frame were excluded. Data regarding age distribution, mortality, immunization, availability of DAT, and diagnostic practices were extracted and synthesized qualitatively.

Results: India continues to report a disproportionate share of global diphtheria cases, approximately 78% as of 2020. PubMed+1 Whereas primary vaccination coverage reached around 78–84%, the booster-dose coverage is low and geographically uneven, with gaps in immunity. Lippincott Journals+1 Several recent outbreaks have shown a shift in the age distribution to older children, adolescents, and even adults. CDC+2IJCMPH+2 The case-fatality rates during outbreaks were reported to range between 15% and 18%, often higher among unimmunized or partially immunized cases. CDC+2PMC+2 Shortages and delays to access DAT have been frequently documented as the global supply has dwindled, and many Indian health facilities lack the stock. Indian Council of Medical Research+2Knowledge Hub+2 Delays in clinical suspicion, a lack of laboratory capacity for toxin confirmation, and low awareness among primary care clinicians impede early diagnosis and treatment. PMC+2IJORL+2

Conclusion: Diphtheria remains a critical public health issue in India. Resurgence is fueled by suboptimal booster immunization, waning immunity, gaps in antitoxin supply, and delays in diagnosis. National surveillance urgently needs strengthening; a reliable supply of DAT should be ensured; incorporation of regular booster doses within immunization programs has to be implemented, and enhancement of clinical and laboratory capacity should be done to facilitate early diagnosis for the mitigation of morbidity and mortality.

Keywords: Diphtheria; India; Antitoxin; Diagnosis; Immunization; Epidemiology.

Introduction

Diphtheria is an acute bacterial infection of the respiratory tract that is caused by toxigenic strains of Corynebacterium diphtheriae. The bacterium elaborates an exotoxin, which results in the formation of a thick grey pseudomembrane in the throat that may obstruct the airway. Complications may include myocarditis, neurological damage, and renal failure; if left untreated, diphtheria may be fatal in up to 30% of case (WORLD HEALTH ORGANISATION, 2024; ICMR, 2025)

Diphtheria has been eradicated from developed nations due to the effectiveness of vaccination campaigns to remove diphtheria from public health. Routine immunization with DPT and DT has been established in India for many years and has led to a total reduction in cases of diphtheria. Unfortunately, the incidence has increased recently in many Indian states. The epidemiology of diphtheria has changed in that it is now reported more frequently in older children, teenagers and adults. This increase may be the result of multiple factors including: the loss of immunity following vaccinations when children reach the age of around 12 years old; lack of booster immunisation throughout their lives; increased movement of people from rural to urban areas; and pockets of communities that are undervaccinated against diphtheria. (Murhekar, 2017; Ray, 2021)

Anti-diphtheria toxins have experienced a global reduction in their supply (via decreased production by many manufacturers) along with the decreased incidence of diphtheria throughout the world. The increased need for anti-diphtheria toxins during diphtheria outbreaks creates a high demand for these treatment options among patients with diphtheria. (ICMR, 2025; Murhekar, 2017) . Early diagnosis is a challenge in many locations for two reasons: First, limited clinical suspicion results in few health care providers ordering

laboratory tests to confirm the presence of toxins. Second, due to a lack of laboratory resources, few if any have the ability to provide this testing (Suligavi et al., 2021)

Due to these concerns, evidence must be compiled and assessed on the availability of antitoxins, as well as the challenges associated with diagnosis. This review will support the current and future development of public health and clinical policy and practice in India**.**

Objective: To examine trends in diphtheria incidence in India over the past 15 years, evaluate the status of antitoxin availability, and identify key challenges in early diagnosis and case management.

Methods

Study design

This is a narrative review based on existing literature, national surveillance reports, and documents from Global Health Organizations published between January 2010 and November 2025.

Data sources and search strategy

Searches were conducted on PubMed and Google Scholar with the following key terms: Diphtheria in India, Diphtheria antitoxin in India, Diphtheria diagnosis challenges, Diphtheria outbreak in India 2022, Diphtheria resurgence in India, and Corynebacterium Diphtheriae in India. We also examined reports published by the World Health Organisation (WHO) and National Public Health Agencies through Policy Briefs regarding Diphtheria in India. Additionally, we manually reviewed the Reference Lists of the relevant articles to identify additional sources.

Inclusion and exclusion criteria

Inclusion: Original research articles, Outbreak Reports, Case Series, Retrospective Observational Studies, and Policy Briefs which addressed Incidence, Immunization Coverage, Antitoxin Supply, and Diagnostic Practice concerning Diphtheria in India between 2010 and 2025.

Exclusion: Non-English publications; Letters/Editions without data. All studies were not dated from the period of 2010-2025 (i.e., were dated before or after); All articles did not relate to epidemiology, Disease Treatment or Diagnosis (i.e., purely genetic/molecular genetic articles without clinical relevance).

Data extraction and synthesis

For each of the selected sources Data was extracted regarding Year; Region/State; Number of Cases; Age Distribution; Immunization Status; Case Fatality; Use and Availability of Antitoxin; Diagnosis Methodologies; Challenges Reported. Extracted Data were Synthesised through Qualitative Analysis. Where appropriate, Tables were compiled which provide a summary of the patterns identified within the studies.

Ethical considerations

This study does not require Ethical Approval as it is a Literature Review of published data (no human participants/patient identifiers involved).

Results

The number of relevant Articles/reports identified whereby they met the inclusion criteria was 18, and they can be categorised into four significant thematic areas – Table describing trends in diphtheria incidence in India over the past 15 years that is from 2010 to 2025; Immunisation coverage/booster gaps; Availability of antitoxin; and Diagnostic difficulties.

Table 1.

Describing trends in diphtheria incidence in India over the past 15 years that is from 2010 to 2025

YEAR	NATIONAL REPORTED CASES	AGE PATTERN (based studies or outbreak available near that year)	SEX PATTERN (from available studies)
2010	3434	In Assam, outbreak showed major burden in 20-44 yrs (40%); only 6.6% in 0-4 yrs -> adult predominance	Male 53.3%, Female 46.7%
2011	4233	Similar pattern to 2010 northeast outbreak – morte adults affected	Slight male predominance reported (approx. 52% male)
2012	2525	Pediatric cases increasing; school-age children more represented in small series	55-60% male in hospital reports
2013	3133	Shift towards children >5 years documented in multiple centers	Mild male predominance
2014	6094	Increasing cases among school-age children (5-10 years)	Around 55% male in scattered reports
2015	2365	Similar pattern -> under-immunized 5-14 years most common	55% male (state studies)
2016	3280	Major outbreak in Kerala; 79% of cases were >10 years, few <5 years -short age shift	For >18 years: 62% male; ≥18 years: 69% female
2017	5293	Nationwide trend: majority of cases in >5 years, adolescent increasingly affected	Based on studies 55-60% male overall
2018	8788	High burden year; most centers reported majority in 5-14 years	Male around 55%

2019	9622	Continued age shift: older children and adolescents	55% males
2020	3485	Based on studies in Gujarat (446 cases): 67% were 5-14 years, 18.8% were 0-4 years	Males 52% and females 48%
2021	1768-3677	According to Gujarat/Jaipur datasets: 5-10 years and 10-14 years were dominant groups.	Male predominance 52-63% depending on region
2022	3286	Gaps in booster coverage – more cases in older & adolescents	According to reports male share approximately 55%
2023	3850	Outbreaks in West Bengal, Karnataka, Assam; majority >5 years clusters in adolescents	55% male
2024	5634	Multiple state re-emergence outbreak; majority 5-19 years, but some adult cases	Based on distinct media and reports male 55-58%

EXACT SSEX RATIO OF DIPHTHERIA IN INDIA

OUTBREAKS/STUDIES	MALE%	FEMALE%	SEX RATIO
Assam outbreak (2010)	53.33	46.67	1.14:1
Kerala outbreak 2016 (<18 yrs)	62	38	1.63:1
Kerala outbreak 2016 (≥18 yrs)	31	69	0.45:1
Gujarat studies 2020-21	52	48	1.08:1
Jaipur hospital studies 2020	62.5	37.5	1.67:1

2. Immunization Coverage and Booster Dose Gaps

- According to the national data, from 2001 to 2016, the coverage of the diphtheria vaccine was between approximately 78% to 84% for the initial three doses (primary doses). (Murhekar, 2017; Ray, 2021)
- However, there is limited information about booster dose coverage in the later childhood and adolescent age groups and the extent to which individuals receive booster vaccinations. As such, people without boosters or who have missed a scheduled booster dose may have a higher likelihood of developing disease due to waning immunity. (Kiran Kumar MaramrajComments to Author, 2021)
- Most of the cases of diphtheria recently reported have occurred in older children and adults, usually in those who were either unimmunized, partially immunized, and did not receive documented booster doses, or had inadequate immunity through other means. (Aiyer & Sovani, 2024)

These findings indicate an existing major immunization gap that is not attributed solely to vaccination during childhood, but also due to inadequate booster vaccination.

3. Availability and Access to Diphtheria Antitoxin

- In India, diphtheria treatment should include antibiotics, the administration of diphtheria antitoxin (DAT) as quickly as possible to neutralize any circulating toxins, particularly for respiratory diphtheria cases. (WORLD HEALTH ORGANISATION, 2024)
- A 2017 policy brief highlighted a lack of access to diphtheria antitoxin(DAT) as one of the main causes of diphtheria-related deaths in India as well as poor immunization coverage and delayed diagnoses as contributing factors. (ICMR, 2025)
- More recently, reports have shown an ongoing shortage of the DAT, primarily due to a contracting global market and a decline in the number of manufacturers, with only a small number of DAT manufacturers remaining by 2025 (including some in India). (National Department of Health, South Africa, 2025)
- In outbreak reports from Karnataka, Assam and other states, there are many references to delayed or limited availability of DAT being a key factor contributing to the increasing mortality rates associated with diphtheria. (Murhekar, 2017)

Therefore, while there are established, effective anti-Diphtheria therapies, the lack of antitoxin stocks is a significant factor in the continuing failure to properly manage diphtheria cases in India.

4. Challenges in Early Diagnosis and Laboratory Confirmation

- Primary-care physicians may not recognize diphtheria cases quickly enough due to atypical presentations or age of the most likely victim. The result is a delay in beginning DAT and obtaining antibiotics. (Suligavi et al., 2021)
- In many parts of the world, laboratories do not have adequate capacity to confirm toxigenic C. diphtheriae either by culture, toxin testing or molecular confirmation; so most outbreak investigations have been reliant on clinical diagnoses with very few laboratories having the ability to perform Albert stain, tox gene PCR, and the Elek test. (Shah & Karanje, 2024)

- During a Kerala outbreak, the cultures taken from patients did not all test positive, and in general, most patients had clinical diagnoses as opposed to laboratory confirmed cases. Delays in providing antitoxin after 72 hours appeared to result in significantly increased rates of neurological complications. (Sindhu et al., 2022)
- Weak or poor case-based surveillance, underreporting, and under-tracing of contacts have made it difficult to detect outbreaks early enough to allow for an effective public health response. (Mohakud, 2024)

These diagnostic issues result in the substantial delays in receiving treatment and make it impossible to control outbreaks effectively.

Discussion

The results of this review show that although India has a long history of having high levels of early childhood immunization coverage (i.e., approximately 90%) for diphtheria, the disease continues to be a major public health problem for India, as evidenced by the fact that diphtheria has not been eliminated from India. There are multiple reasons that contribute to the current re-emergence of diphtheria and its continued high fatality rates in diphtheria outbreaks.

The first thing that stands out is the apparent immunity gap against diphtheria. While the coverage of the primary immunization (i.e., three doses) is reasonably good (allowed to be reasonably well, approximately 78% to 84%), there has been little or no documentation of the coverage of the booster dose in children and adults, which is a critical factor for maintaining immunity after primary immunization into the age range of school age children and the adult community. The increasing number of cases in older children and adolescents and adults indicates a decrease in acquired immunity over time. (Ray et al., 2021)

The second factor affecting diphtheria in India is the lack of reliable availability of diphtheria antitoxin. Diphtheria antitoxin (DAT) is the only effective drug available to neutralize diphtheria toxin, and with the continued decline of DAT being manufactured worldwide, there are now many healthcare organizations in India that do not have enough DAT stock available and are unable to administer DAT in a timely manner. (Roy, 2017) his has likely been a major contributor to the diphtheria case-fatality rates of 15-18% reported for outbreaks in India in recent years.

Third, Delays in diagnosis and limited laboratory capacity hinder appropriate case management because clinical suspicion is frequently low (particularly in older patients or those presenting with a non-classical presentation). Additionally, most health centers do not have the capacity to perform confirmatory testing (i.e., culture, toxigenicity assays, molecular diagnostics), relying solely on a clinical diagnosis to confirm diphtheria. A delay in diagnosis will subsequently translate into a delay in administering DAT, therefore minimizing the effectiveness of DAT administration. (Gupta et al., 2020)

Fourth, gaps in diphtheria surveillance and reporting system — including underreporting, inadequate contact tracing, and lack of case-based surveillance — delay timely public health responses to diphtheria outbreaks. This, in turn, contributes to silent transmission and delays the identification of diphtheria outbreaks. (Mohakud, 2024)

This is a significant public health issue. While diphtheria is preventable and treatable, it is theoretically eradicable since the virus does not have any known animal hosts. The gaps in immunisation, diagnostics, and antitoxin supply will continue to hamper efforts to control diphtheria.

Strengths and limitations of this review: The comprehensive literature search (January 2010 through December 2025) of this review provides current pattern/ trend/ issue data across multiple regions of India. However, since this is a narrative review, a meta-analysis has not been provided. The heterogeneity of the data (differences in settings, case definition, age category, and reporting standards) also limits any quantitative analysis possible. Many articles reviewed did not provide either the exact immunisation histories or the exact timing of when the patient received antitoxin administration.

Conclusion

Despite extensive vaccination campaigns, diphtheria continues to be a significant burden in India. In recent years, the re-emergence of the disease has shown patterns of age-shifting, high case-fatality rate, and the appearance of outbreaks across many different geographical areas in India. The resurgence of diphtheria demonstrates that immunization programme has not maintained or provided adequate population immunity and is failing to fill the gaps in clinical management of diphtheria cases. The limited availability of diphtheria antitoxin and the inability to make timely early diagnoses of diphtheria cases will continue to increase the amount of illness and death caused by the disease. A comprehensive plan consisting of several coordinated strategies is necessary to effectively control the disease, including the provision of adequate booster doses, improvement in diagnostic and clinical management capabilities, continued availability of diphtheria antitoxin (DAT), and enhancement of surveillance capabilities. If these are not done, diphtheria is likely to continue to be a frequent and increasing public health threat to the residents of India.

References

1. Maramraj KK, Kaur S, Dikid T, et al. Addressing Reemergence of Diphtheria among Adolescents through Program Integration in India. *Emerg Infect Dis*. 2021;27(3). CDC

2. Basavaraja GV, Chebbi PG, Joshi S. Resurgence of diphtheria: clinical profile and outcome – a retrospective observational study. *Int J Contemp Pediatr*. 2016;3(4). Int J Contemp Pediatr+1

3. Sampurnanand Med College Study. Clinico-Epidemiological Profile of Pediatric Diphtheria Cases in Western India (Rajasthan) 2019. PubMed+1

4. Aiyer S, Sovani V. Out of the blue presentation: diphtheria cases in Vadodara. *IJCM & PH*. 2024–2025. IJCMPH

5. Drishti Sagar. Resurgence of diphtheria cases in India: where are we lacking? *The Evidence*. 2024;2(3). the.evidencejournals.com

6. Indian Journal of Pathology & Microbiology. Diphtheria case detection and carrier study — North Karnataka 2024. Lippincott Journals+1

7. Assam Medical College et al. Recent Outbreaks of Diphtheria in Dibrugarh District, Assam, India. 2024. PMC

8. Shashidhar SS, Vishwanath D, Gokale S, Doddamani SS. Diphtheria: a re-emerging infectious disease. *Int J Otorhinolaryngol Head Neck Surg*. 2021. IJORL

9. World Health Organization. Diphtheria fact sheet. 2025. World Health Organization

10. ICMR / NITM Policy Brief. Diphtheria: A battle not yet won… 2017. Indian Council of Medical Research

11. Global report: Supply of Diphtheria Antitoxin (DAT) — implications of limited global and national supply, 2025. Knowledge Hub

12. Historical epidemiology review: Epidemiology of Diphtheria in India 1996–2016: Implications for Prevention and Control. PMC. PMC

THE DIAGNOSTIC VALUE OF ULTRASOUND ARTIFACTS IN THE MANAGEMENT OF COVID-19 PNEUMONIA

Noniashvili M.,
Kandashvili T.,
Giorgadze L.
Tbilisi State Medical University. Department of Internal Medicine #3
The First University Clinic
DOI: 10.5281/zenodo.18614904

Abstract

Lung ultrasonography (LUS) has emerged as a non-invasive, rapid, and reliable diagnostic modality for COVID-19 pneumonia. By analyzing pleural artifacts, including horizontal A-lines and vertical B-lines, LUS allows detection of interstitial syndromes, consolidations, and pleural irregularities. In this study, 50 hospitalized patients with confirmed or suspected COVID-19 were examined using standardized BLUE and CLUE protocols across 3, 6, and 12 lung zones, with comparative analysis to computed tomography (CT). Findings demonstrate that LUS provides accurate bedside assessment, detects early pathological changes, monitors disease progression, and differentiates viral from bacterial pneumonia. LUS is particularly valuable in emergency, ward, and intensive care settings, offering a cost-effective, radiation-free, repeatable alternative to CT.

Keywords: Lung ultrasonography, COVID-19, B-lines, A-lines, BLUE protocol, CLUE protocol, interstitial pneumonia, critical care.

Ultrasound examination of the organ with the largest volume in the human body—the lung—had long been considered uninformative. A normally aerated healthy lung represents a major acoustic barrier to ultrasound. However, deeper investigation into the subject has revealed not only the feasibility of sonography but also its real and potential benefits in the diagnosis and management of emergency cases presenting with dyspnea [1–3].

The pioneer of lung ultrasonography is considered to be the intensivist and anesthesiologist Professor Daniel Lichtenstein from the Ambroise-Paré University Hospital in Paris, who in 1991 developed the method of so-called “critical ultrasound”—a comprehensive approach to ultrasound examination in emergency and critical care settings, including thoracic organs and lungs, alongside transthoracic echocardiography [2,3].

The analysis of this examination is based on artifacts originating from the pleura. Since most acute respiratory disorders involve the pleura, this structure is accessible to ultrasound. The hyperechogenic pleural line consists of the parietal and visceral pleura with the potential space between them. Normally, it moves synchronously with the respiratory cycle—a phenomenon known as lung sliding. The absence of lung sliding indicates pneumothorax with 100% specificity [1,4,5].

Lung ultrasonography identifies several sonographic signs, some of which are characteristic of normally aerated lungs, while specific combinations of these signs may indicate pathological processes. The semiology of lung ultrasound includes artifacts generated at air–tissue interfaces [1,4,5]. These artifacts are classified as horizontal (A-lines) and vertical (B-lines).

A-lines are horizontal reverberation artifacts appearing at equal distances from each other, corresponding to the thickness of the soft tissues between the skin and pleura. They can be seen both in normal lungs and in various pathologic conditions, depending on the combination of findings [1,4].

B-lines are vertical artifacts that arise from the pleural line and extend to the bottom of the screen without fading. They are observed in both normal lungs and in lungs with various degrees of deaeration. The presence of three or more B-lines between two ribs is referred to as “lung rockets” and correlates with interstitial syndrome, showing a 93% sensitivity for alveolar–interstitial radiographic changes and complete concordance with findings on computed tomography. When fewer than three B-lines are visible (“septal rockets”), this corresponds to Kerley B-lines on chest radiography and indicates thickened interlobular septa seen in interstitial syndrome [5,6].

Several protocols have been developed for lung ultrasonography, each designed for specific clinical purposes. For the differential diagnosis of diseases causing acute dyspnea, the BLUE protocol (Bedside Lung Ultrasound in Emergency) is widely applied. In addition, based primarily on echographic assessment of the lungs, the FALLS protocol (Fluid Administration Limited by Lung Sonography) serves as a valuable tool for determining therapeutic strategies in cases of shock of unknown etiology [7].

According to these protocols, examination of the patient is performed using three-point scanning for each hemithorax: the right and left anterior upper BLUE points, the anterior lower BLUE points, and the posterolateral alveolar and/or pleural syndrome (PLAPS) points on both sides.

Three standardized points are identified:

1. Upper BLUE point – located in the middle of the upper hand.
2. Lower BLUE point – located in the middle of the lower hand.
3. PLAPS point – defined as the intersection of a horizontal line drawn at the level of the lower BLUE point and the vertical posterior axillary line [7].

The use of small-footprint probes allows positioning as posteriorly as possible in supine patients, thereby enhancing the sensitivity for detecting posterolateral al-

veolar and/or pleural syndromes (PLAPS). The diaphragm is typically located at the lower margin of the lower hand [20].

Using the BLUE protocol, it is possible to accurately diagnose a wide range of pulmonary pathologies, including pneumothorax (with diagnostic accuracy comparable to computed tomography and higher specificity than chest radiography), pleural effusion, pulmonary edema, interstitial syndrome, pneumonia, atelectasis, pulmonary embolism, and chronic obstructive pulmonary disease (COPD) [9,10].

Lung ultrasonography can play a significant role during the SARS-CoV-2 pandemic. Based on lung ultrasound findings and clinical data from the Molinette MedUrg Group on Lung Ultrasound, in cases with false-negative results during early PCR testing, diagnosis can be established with an accuracy of up to 94.4% [11,12].

During the progression of COVID-19, parenchymal changes in the lungs typically begin in the distal regions and progressively extend proximally. In the early phase, computed tomography (CT) often demonstrates a “ground-glass” pattern and a “crazy paving” appearance, whereas in later stages, larger consolidations are observed, primarily in the basal or dependent lung regions. The most frequently affected regions are the right middle and lower lobes, followed by the left upper lobe.

Histopathologically, COVID-19 pneumonia progresses in the distal lung regions and is characterized by alveolar damage and edema, interstitial thickening, and gravity-dependent consolidations. Consequently, the pathological progression of COVID-19 pneumonia is well suited for surface visualization techniques, such as lung ultrasonography [8].

The clinical presentation of COVID-19 is highly variable, ranging from asymptomatic infection to severe, life-threatening pneumonia with major complications. Severe disease typically develops approximately one week after symptom onset, characterized by rapidly progressing respiratory failure and acute respiratory distress syndrome (ARDS)—bilateral, non-cardiogenic pulmonary edema caused by fluid overload, leading to severe hypoxemia.

Although the pathophysiology of lung injury in COVID-19 meets the Berlin criteria for ARDS, COVID-19 pneumonia is described as exhibiting two phenotypes: “non-ARDS” (Type I) and “ARDS” (Type II). Among imaging modalities, computed tomography (CT) of the lungs remains the gold standard. Therefore, the efficacy and utility of other imaging techniques, including ultrasonography, are primarily assessed in comparison with CT findings [13,14]. (Table 1).

Table 1.

Characteristics of **COVID-19 pneumonia** on **computed tomography (CT)** and **lung ultrasonography**. Adapted from Peng QY, Wang XT, Zhang LN. Findings of lung ultrasonography of novel coronavirus pneumonia during the 2019–2020 epidemic. Intensive Care Med. 2020;46(5):849–850. [21].

Lung CT	LUS
Thikened pleura	Tikened pleural line
Ground glass opacity	B-lines(multifocal,discrete,or confluent)
Infiltrating shadows	Confluent B-lines
Sub-pleural consolidation	Small consolidations
Translobar consolidation	Non-translobar+translobar consolidations
Rare pleural effusions	Rare pleural effusions
More than two pulmonary lobes affected	Conspicous features distributed on a multilobar basis

Since COVID-19 pneumonia most frequently exhibits peripheral, superficial involvement, predominantly affecting the lower lobes, the pathological changes are accessible to lung ultrasonography (with a penetration depth of 14–16 cm). Lung ultrasound is particularly advantageous in the emergency department during the pandemic due to its availability, high diagnostic accuracy for pulmonary diseases, and low cost.

Lung ultrasonography can be performed using linear, curved (abdominal), or sector (cardiac) probes. During the examination, the probe is positioned parallel or perpendicular to the intercostal spaces. Recommended imaging depth is 8–10 cm (6–8 cm in asthenic individuals, 10–12 cm in hypersthenic individuals).

The examination is performed sequentially, starting from the most frequently affected regions toward the less affected areas: from the dorsal surfaces, progressing caudally to cranially, then moving to lateral, and finally anterior surfaces. Each region is observed over approximately one respiratory cycle (5–6 seconds). The number of artifacts is recorded per intercostal space.

The Lichtenstein nomenclature using the so-called Volpicelli zones is applied [1516,17,18], with six regions per hemithorax. Each region is evaluated using a three-point scoring system.

The lung ultrasound score (LUS) is a semi-quantitative model that considers 12 regions and the presence of specific artifacts resulting from extravascular fluid accumulation and/or loss of aeration. The total score ranges from 0 to a theoretical maximum of 36 points (consolidation in all regions). [22].

For the ultrasound assessment of patients, the CLUE protocol was developed by Australian intensivists and trainees, enabling the triage of COVID-19 patients based on a lung ultrasound scoring system [19]

Based on the existing knowledge of lung ultrasound and the experience gained in European countries, from December 2020 we decided to implement lung ultrasound for patients in the therapeutic ward. Each patient was evaluated within the clinical context, incorporating laboratory and instrumental findings as well as objective clinical data, with particular emphasis on the analysis of computed tomography (CT) results.

Ultrasound examinations were performed according to both established lung ultrasound protocols (BLUE and CLUE), assessing 3, 6, and 8 zones per lung, with patients examined in both supine and seated positions. Notably, the 12-zone assessment, as outlined in the CLUE protocol, was considered the most optimal approach for evaluating COVID-19 patients.

During the process of practically applying the fundamental principles of lung ultrasound, approximately 50 patients were examined dynamically to ensure that the results could be interpreted reliably both technically and clinically. In total, up to 90 examinations were conducted across the following groups (laboratory-confirmed COVID-19):

1. Patients with prolonged fever
2. Patients on the first day of hospitalization
3. Patients presenting with clinical manifestations of COVID-19 but negative PCR results
4. Pregnant patients
5. Patients with community-acquired pneumonia (PCR-negative)

The following section presents selected ultrasound findings from these examinations.

Patient N1: Male, 61 years old (Figure 1). The patient was admitted to the clinic on March 5, 2021. On the same day, lung ultrasound (LUS) examination revealed consolidations in zones R6 and R4 on the right lung, while B-lines were observed in all other zones bilaterally, except in R1, L1, and L2, with more than three B-lines per intercostal space and occupying >50% of the examined area. The total ultrasound score was 11–12 points.

Chest CT of the same patient demonstrated bilateral, patchy, small- to medium-sized ground-glass opacities, predominantly in the basal regions, with small consolidative foci. Semi-quantitative analysis of CT images yielded a lung involvement index of 12 points (scale 0–24) (Table 2).

Comparative Analysis: LUS vs CT

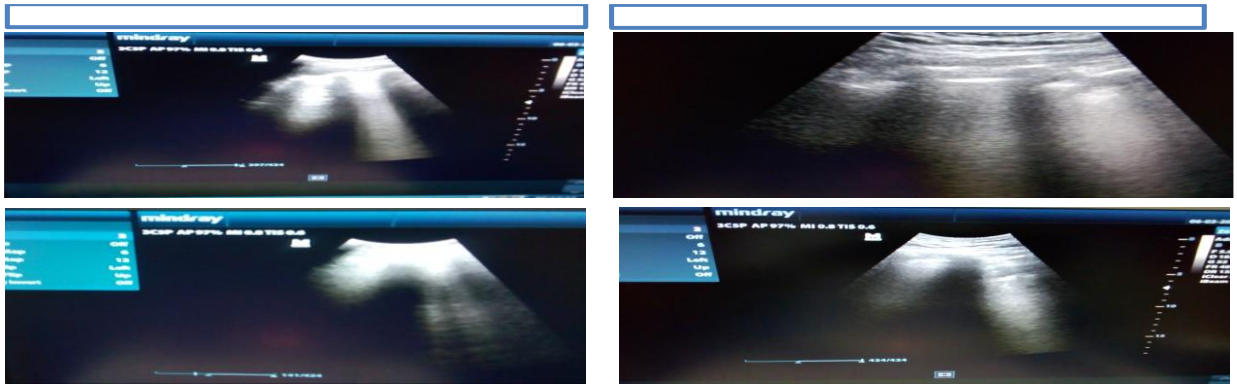
Parameter	Lung Ultrasound (LUS)	Computed Tomography (CT)
Extent of involvement	11–12 points – diffuse B-lines and consolidations	12 points – ground-glass opacities + consolidations
Localization	R6, R4 – consolidation; B-lines bilaterally	All lung fields bilaterally, predominantly basal
Detail	Consolidation and interstitial pattern	Precise localization, type, and volume of lesions
Advantages	Rapid, bedside, radiation-free	High accuracy and detailed visualization
Limitations	Incomplete visualization of deep zones	Radiation exposure, high cost, difficult transport

Conclusion:

Both methods (LUS and CT) provided consistent and reliable information regarding interstitial and alveolar involvement characteristic of COVID-19 pneumonia.

Lung ultrasound demonstrated a good correlation with CT findings, particularly in terms of B-line distribution and consolidations.

Accordingly, LUS can be considered an effective and rapid alternative for assessment of severely ill or urgent patients; however, final diagnosis and precise volumetric assessment of pulmonary involvement remain dependent on CT imaging.



Patient N1: Male, 61 years old (Figure 1).

Table 2.

Lung ultrasound by zone in Patient N1

Zone	B-lines / Thickened pleural line	Subpleural consolidation	Large consolidation / Air bronchogram
R1	-	-	-
R2	+	-	-
R3	+	-	-
R4	-	+	-
R5	+	-	-
R6	-	+	-
L1	-	-	-
L2	- / +	-	-
L3	+	-	-
L4	+	-	-
L5	+	-	-
L6	+	-	-
Total	11–12 points	-	-

Patient N2: Female, 55 years old (Figure 2). The patient was admitted on March 12, 2021. Chest CT demonstrated ground-glass opacities with pronounced interstitial thickening. Lung ultrasound (LUS) was performed on March 16, 2021. In all examined regions except L1 and L2, multiple and confluent B-lines ("waterfall sign") were observed, with associated pleural thickening. The total ultrasound score was 10 points (Table 3).

CT imaging of this patient showed bilateral, peripherally localized, small ground-glass nodular opacities with interstitial thickening across multiple lung fields. Semi-quantitative analysis of the CT data yielded a lung involvement index of 6 points (scale 0–24).

Due to clinical and laboratory deterioration, the patient was subsequently transferred to the intensive care unit (ICU). A repeat chest CT with semi-quantitative analysis showed an increased lung involvement index of 16 points (scale 0–24).

- The initial CT findings were lower than the LUS score.
- During follow-up, it became apparent that LUS detected more severe early-stage involvement than the initial CT.

Comparative Analysis: LUS vs CT

Parameter	Lung Ultrasound (LUS)	Computed Tomography (CT)
Extent of involvement	10 points – multiple B-lines and waterfall sign	Initially 6 points, subsequently 16 points
Details	Intense interstitial involvement, pleural thickening	Ground-glass nodules, interstitial thickening
Level of detail	Rapid visualization of peripheral lesions	Precise volumetric assessment across all segments
Possible interpretation	Disease already in a progressive phase at the time of LUS	Initial CT may have underestimated disease extent
Limitations / Advantages	Identified progressing lesions – early detection	Radiation exposure, high accuracy, but delayed representation of progression

Conclusion:

In this case, lung ultrasound (LUS) detected significant pathological changes early (10 points), which were not fully visualized on the initial CT scan (6 points). During follow-up, as the patient's clinical status worsened, the CT involvement index markedly increased (16 points), confirming the high sensitivity of LUS for early detection of disease progression.

This case highlights the value of LUS as a monitoring and early detection tool, particularly in patients whose clinical condition changes rapidly.

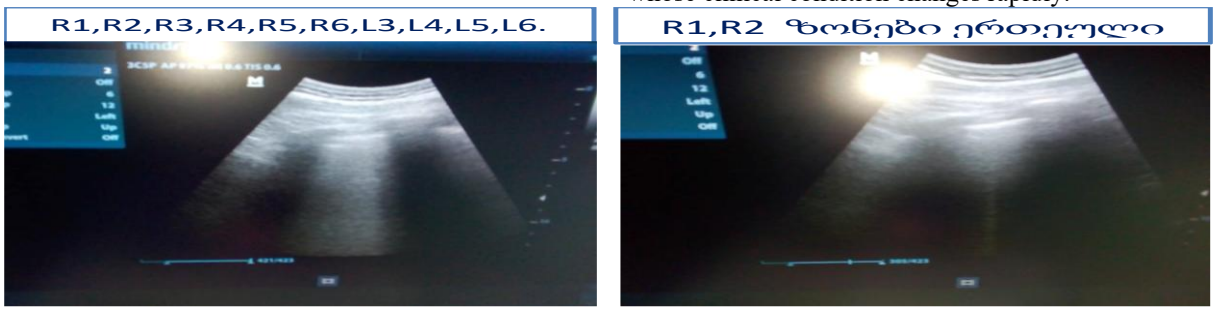


Figure 2

Table 3.

Lung ultrasound findings by zone in Patient N2

Zone	B-lines / Thickened pleural line	Subpleural consolidation	Large consolidation / Air bronchogram
R1	+	-	-
R2	+	-	-
R3	+	-	-
R4	+	-	-
R5	+	-	-
R6	+	-	-
L1	-	-	-
L2	-	-	-
L3	+	-	-
L4	+	-	-
L5	+	-	-
L6	+	-	-
Total	10 points	-	-

Patient N3: Female, 62 years old (Figure 3). The patient was admitted on March 10, 2021. Lung ultrasound (LUS) was performed on March 13, 2021. In the anterior zones and upper lateral point on the left, no pathological changes were observed. The total LUS score was 7–8 points (table4). Chest CT demonstrated typical ground-glass opacities.

CT imaging showed bilateral diffuse reduction in lung transparency, with small, isolated ground-glass opacities in various lung fields. Semi-quantitative analysis of the CT data yielded a lung involvement index of 4 points (scale 0–24).

Comparative Analysis: LUS vs CT

Parameter	Lung Ultrasound (LUS)	Computed Tomography (CT)
Extent of involvement	7–8 points – mostly limited changes	4 points – isolated ground-glass changes
Details	No involvement in anterior left zones; focal B-lines	Diffuse reduction in transparency; discrete lesions
Level of detail	Good sensitivity at zonal level	Precise segmental assessment
Possible interpretation	Adequate correlation with CT in mild cases	Confirms LUS evaluation of minor lesions
Limitations / Advantages	Simple, bedside applicable	Requires patient mobilization; detailed imaging

Conclusion:

In patient N3, both lung ultrasound (7–8 points) and chest CT (4 points) demonstrated mild, focal pulmonary lesions. The results of both modalities were consistent, highlighting the reliability of LUS in diagnosing mild cases. The absence of findings in the left anterior and upper lateral zones underscores the zonal specificity of LUS.

This case demonstrates that LUS, despite its limitations in deep lung structures, effectively reflects mild disease, especially when CT is unavailable or not immediately feasible.

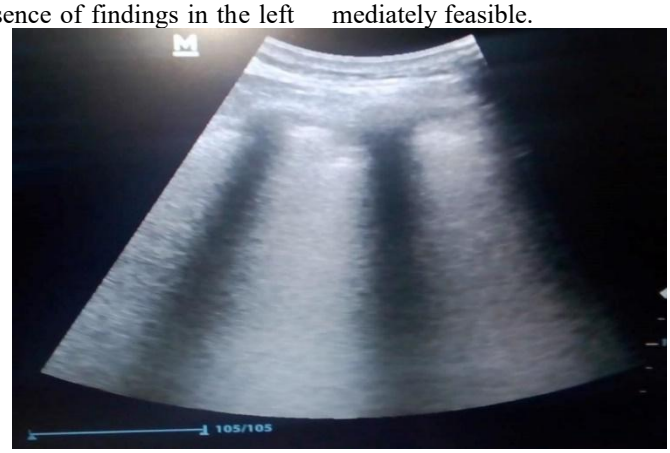


Figure 3

Table 4.

Lung ultrasound fi by zone in Patient N3

Zone	B-lines / Thickened pleural line	Subpleural consolidation	Large consolidation / Air bronchogram
R1	-	-	-
R2	-	-	-
R3	+	-	-
R4	+	-	-
R5	+	-	-
R6	+	-	-
L1	-	-	-
L2	-	-	-
L3	-	-	-
L4	+	-	-
L5	+	-	-
L6	+	-	-
Total	7–8 points	-	-

Patient N4 – Male, 49 years old (Fig. 4)

The patient was admitted on 08/01, with COVID-19 confirmed since 04/01. CT assessment showed a lung damage index of 5 points on 08/01, which increased to 22 points on 14/01. Lung ultrasound (LUS) was performed on 20/01 and assessed at 16 points (Table 5).

Comparative analysis: LUS vs CT

Parameter	Lung Ultrasound (LUS)	Computed Tomography (CT)
Extent of involvement	16 points – progressive, widespread lesions	08/01 – 5 points; 14/01 – 22 points
Details	Focal lesions, likely with consolidations and prominent B-lines	Diffuse ground-glass opacities, likely with consolidations
Level of detail	Possible waterfall signs and pleural alterations	Accurate assessment of structural and volumetric damage
Possible interpretation	Acute phase of disease – already progressed	Evolutionary course corresponds to LUS findings (CT performed 6 days earlier)
Limitations / Advantages	Performed during peak phase – confirms high-risk features	Allows dynamic assessment at early and late stages

Conclusion:

In Patient N4, the clinical course demonstrated rapid disease progression, with the CT lung damage index increasing fivefold within six days (5 → 22 points). The LUS performed on 20/01 showed a high score (16 points), corresponding to the acute stage of the disease and effectively confirming the severe damage observed on CT. This case further highlights the high diagnostic value of LUS in acute and dynamically progressive COVID-19 pneumonia.

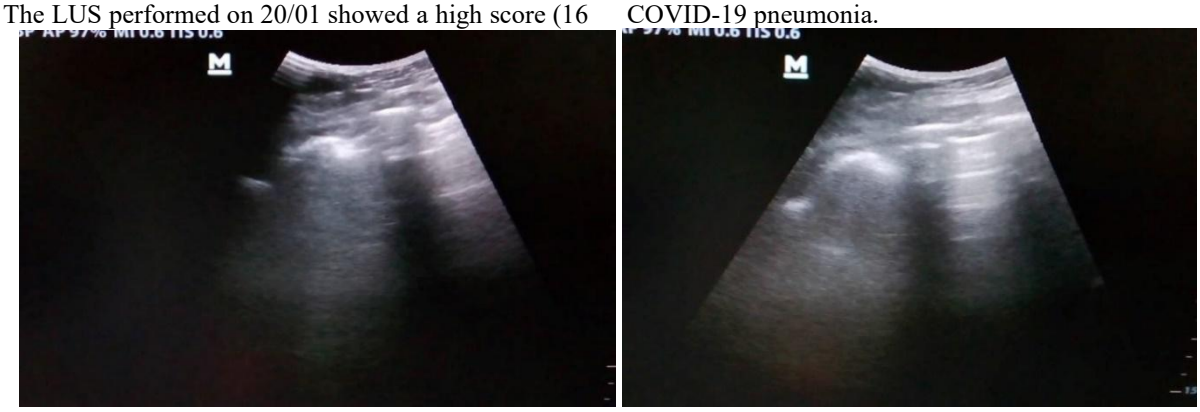


Figure 4

Table 5.

Lung ultrasound findings by zone in Patient N4

Zone	B-lines / Thickened pleural line	Subpleural consolidation	Large consolidation / Air bronchogram
R1	+	-	-
R2	+	-	-
R3	+	-	-
R4	-	+	-
R5	-	+	-
R6	-	+	-
L1	-	-	-
L2	-	-	-
L3	+	-	-
L4	-	+	-
L5	+	-	-
L6	+	+	-
Total	16point	-	-

Patient N5, female, 63 years old (Figure 5). The patient presented on 17/03 with symptoms suggestive of COVID-19; however, both rapid antigen and PCR tests were negative. According to the medical history, she had experienced intermittent fever, arthralgia, general weakness, anosmia, and ageusia since early February. She had previously been treated in another facility for presumed pneumonia, without laboratory confirmation of COVID-19. Despite empirical treatment for 4–5 days, fever persisted, prompting hospital admission. Chest X-ray demonstrated bilateral infiltrates.

Lung ultrasound (LUS) was performed on 17/03 and revealed COVID-19–like alterations: irregular, thickened pleural line and >3 B-lines per intercostal space were observed in R3, R4, R5, R6, L4, L5, and L6 zones.

Conclusion:

In this case, despite the lack of laboratory confirmation for COVID-19, the combination of clinical symptoms (anosmia, ageusia, fever, fatigue) and imaging features (bilateral infiltrates on X-ray and characteristic LUS findings) strongly suggests the presence of COVID-19–like viral pneumonia. This case underscores the diagnostic value of lung ultrasound even when laboratory confirmation is unavailable or inconclusive.

Figure 5

Patient N6, pregnant, 35 weeks gestation (Figure 6). The patient, 30 years old, was admitted on 25/05 with laboratory-confirmed COVID-19 (diagnosed on 16/05). She presented with persistent low-grade fever and SpO_2 of 95%. Lung ultrasound (LUS) was performed on 25/05 and revealed multiple B-lines in L5, L6, R4, R5, and R6 zones. Thickened, irregular pleural lines were observed in L6, R5, and R6 zones.

In healthy pregnant patients, especially in the third trimester, the physiologically elevated diaphragm due to the enlarged uterus naturally reduces lung excursion and may result in fluid accumulation. This often manifests as B-lines in the posterior-basal zones bilaterally on LUS, which are characteristic of an interstitial pattern. In this patient, the presence of irregular and thick-

ened pleural lines allows differentiation between physiological changes associated with pregnancy and COVID-19–related alterations. (Table 6)

Clinical Interpretation:

- LUS findings are consistent with mild COVID-19–associated interstitial pneumonia.
- Alterations are localized to typical zones (posterior-basal).
- Pathological pleural line changes serve as the main differentiating feature from physiological pregnancy-related changes.
- SpO_2 of 95% and low-grade fever indicate clinically stable condition without severe respiratory involvement.

Conclusion:

Lung ultrasound in this 35-week pregnant patient with laboratory-confirmed COVID-19 revealed multiple B-lines and irregular pleural lines across several zones, indicative of interstitial changes. While third-trimester pregnancy is associated with physiological lung changes, the pleural line is not part of normal B-line physiology; therefore, these findings should be considered pathological. Overall, LUS provided reliable evidence of COVID-19–associated mild interstitial pneumonia in the context of pregnancy.

Figure-6

Table 6.

Lung ultrasound findings by zone in Patient N6

Zone	B-lines / thickened pleural line	Subpleural consolidation	Large consolidation / air bronchograms
R1	–	–	–
R2	–	–	–
R3	–	–	–
R4	+	–	–
R5	+	+	–
R6	+	+	–
L1	–	–	–
L2	–	–	–
L3	–	–	–
L4	–	–	–
L5	+	–	–
L6	+	+	–
Total Score	11 points	–	–

Patient N7: Male, 53 years old (Figure-7). Admitted on 18/03 with right-sided pneumonia. Radiographically, there was a perihilar infiltration on the right side. Lung ultrasound performed on 21/03 revealed consolidation in the right lower anterior region (R2 point).

LUS capabilities in bacterial pneumonia:

- Lung ultrasound successfully identified localized consolidation, strongly suggesting bacterial etiology.
- Unlike COVID-19, where interstitial involvement and B-lines dominate across multiple zones, in this case the pathology is localized and consolidative.

- LUS can not only confirm the presence of pneumonia but also help differentiate between viral and bacterial types based on localization, type of consolidation, and pleural line changes.

Conclusion:

Patient N7 represents a classic example of non-viral pneumonia, in which lung ultrasound effectively confirmed localized consolidation consistent with radiographic findings. This case demonstrates that LUS is not limited to COVID-19 detection, but serves as a reliable method for diagnosing pulmonary pathologies, particularly when the involvement is localized and bacterial in nature.

Figure-7

Table-7

The table presents the laboratory, instrumental, and clinical data of several patients described above.

patiet	N1	N2	N3	N4	N5	N8	N9
date	5/03/21	12/03/21	10/03/21	24/04/21	17/03/21	7/05/21	6/05/21
Age/sex	61y/m	55y/f	62y/f	40y/f	63y/f	51y/m	45y/m
Ct score	12p	6/16p	4/9p	0/15	-	13p	17p
Lus-score	11/12p (5/03)	10p (13/03)	7–8p (13/03)	13p (8/05)	7-8p (17/03)	11p (8/05)	12p (8/05)
EF	56%	58%	56%	62%	60%	56%	60%
pasp	31mmhg	27mmhg	30mmhg	23mmhg	26mmhg	30mmhg	23mmhg
Chronic diseases	-	-	DM2, CABG	–	HTN	DM2	CKD crea-208
PCR	+	+	+	+	–	+	+
CRP	99mg/L	13mg/L	11mg/L	25mg/L	179mg/L	98mg/L	110mg/L
LDH	264U/L	282U/L	195U/L	197U/L	-	242U/L	318U/L
TROP	0,010µg/L	0,010µg/L	0,010µg/L	0,010µg/L	-	0,010µg/L	0,010µg/L
D.DIM	169(243) ng/ml	214(651) µg/L	328(651) µg/L	0,64 (0.5) mg/l	-	2,7 (0.5) mg/l	1150(651) µg/L
EOZ	0,4%	1,9%	0,7%	0.0	1.3%	0.3%	0.3%
NLR	4	3	7	11	5	5	6
SPO2 -AA	93%	92%	93%	90%	89%	92%	91%
T	38,0C	38,50C	37,40C	38,50C	37.50C	37.8oC	36.8oC

The patients presented in the table were treated in a general medical ward, with patient N2 later transferred to the intensive care unit. As the data indicate, the ultrasound (LUS) scores ranged from 5 to 15, corresponding to moderate severity according to the CLUE protocol. For patients with moderate pulmonary involvement who are oxygen-dependent, the protocol recommends continuing treatment in the general medical ward, while also considering the potential need for intensive care.

In summary, lung ultrasound in the medical ward represents a highly sensitive, versatile, and safe diagnostic tool with several advantages:

- It effectively detects typical COVID-19 findings, including multiple B-lines, consolidations, and pleural changes.
- It informs clinical decision-making even in the absence of laboratory or radiological confirmation.
- It facilitates rapid decision-making in high-risk groups (e.g., pregnant patients) [25] without ionizing radiation.
- It demonstrates high specificity in distinguishing non-viral, bacterial pneumonia from COVID-19.

In conclusion, the advantages and potential applications of lung ultrasound can be summarized as follows: it is non-invasive, rapid, and repeatable; it allows visual assessment of pathological processes, including in pregnant patients, for both COVID-19 and other pleuro-pulmonary conditions. During the COVID-19 pandemic, lung ultrasound has proven to be a valuable adjunct at various stages: for triage in emergency departments, monitoring patients in internal medicine wards, and in intensive or critical care units for risk stratification, complication prediction, and treatment efficacy monitoring. Additionally, lung ultrasound can

be applied in clinical research across multiple contexts and settings.

References

1. Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med*. 2012;38:577–591. doi:10.1007/s00134-012-2513-4. PMID: 22392020.

2. Lichtenstein DA. Lung ultrasound in the critically ill. *Ann Intensive Care*. 2014;4:1. doi:10.1186/2110-5820-4-1. PMID: 24359555.

3. Lichtenstein D. *Whole body ultrasonography in the critically ill*. Springer; 2010.

4. Soldati G, Smargiassi A, Inchingolo R, et al. Proposal for international standardization of the use of lung ultrasound for COVID-19 patients. *J Ultrasound Med*. 2020;39:1413–1419. doi:10.1002/jum.15285. PMID: 32298150.

5. Poggiali E, Dacrema A, Bastoni D, et al. Can lung US help critical care clinicians in the early diagnosis of novel coronavirus (COVID-19) pneumonia? *Radiology*. 2020;296:E6–E6. doi:10.1148/radiol.2020200957. PMID: 32169637.

6. Yasukawa K, Minami T. Point-of-care lung ultrasound findings in patients with novel coronavirus disease (COVID-19) pneumonia. *Am J Trop Med Hyg*. 2020;102:1198–1202. doi:10.4269/ajtmh.20-0289. PMID: 32329401.

7. Lichtenstein DA. BLUE-protocol and FALLS-protocol. *Chest*. 2015;147:1659–1670. doi:10.1378/chest.14-2882. PMID: 25783875.

8. Smith MJ, Hayward SA, Innes SM, Miller ASC. Point-of-care lung ultrasound in patients with COVID-19–a narrative review. *Anaesthesia*. 2020;75:1096–1104. doi:10.1111/anae.15082. PMID: 32405501.

9. Volpicelli G, Caramello V, Cardinale L, et al. Lung ultrasound in emergency and critically ill patients: number of studies and accuracy. *Chest*. 2012;141:1177–1183. doi:10.1378/chest.11-2401. PMID: 22539348.

10. Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest*. 2008;134:117–125. doi:10.1378/chest.07-2800. PMID: 18574271.

11. Nouvenne A, Zani MD, Milanese G, et al. Lung ultrasound in COVID-19 pneumonia: correlations with chest CT on hospital admission. *Respir Med*. 2020;165:105954. doi:10.1016/j.rmed.2020.105954. PMID: 32607606.

12. Buonsenso D, Pata D, Chiaretti A. Point-of-care lung ultrasound findings in novel coronavirus disease-19 pneumonia: a prospective study. *J Ultrasound Med*. 2020;39:1877–1884. doi:10.1002/jum.15284. PMID: 32421440.

13. Huang Y, Wang S, Liu Y, et al. A preliminary study on the ultrasonic manifestations of peripulmonary lesions of non-critical novel coronavirus pneumonia (COVID-19). *SSRN Electron J*. 2020. doi:10.2139/ssrn.3544750.

14. Reissig A, Copetti R, Kroegel C. Lung ultrasound in community-acquired pneumonia and in interstitial lung diseases. *Respiration*. 2014;87:179–189. doi:10.1159/000357980. PMID: 24240549.

15. Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med*. 2012;38:577–591. doi:10.1007/s00134-012-2513-4.

16. Lichtenstein DA. *Whole body ultrasonography in the critically ill*. Springer; 2010.

17. Volpicelli G, Gargani L. Sonographic signs and patterns of COVID-19 pneumonia. *Ultrasound J*. 2020;12:22. doi:10.1186/s13089-020-00171-w.

18. Soldati G, Smargiassi A, Inchingolo R, et al. Lung ultrasonography for patients with COVID-19: a narrative review. *Ultrasound Med Biol*. 2020;46:1291–1300. doi:10.1016/j.ultrasmedbio.2020.04.021.

19. Manivel V, Lesnewski A, Shamim S, Carbonatto G, Govindan T. CLUE: COVID-19 lung ultrasound in emergency department. *Emerg Med Australas*. 2020;32:1–6. doi:10.1111/1742-6723.13546.

20. Lichtenstein DA. *Whole Body Ultrasonography in the Critically Ill*. Springer; 2010. Chapter 14.

21. Peng QY, Wang XT, Zhang LN. Findings of lung ultrasonography of novel coronavirus pneumonia during the 2019–2020 epidemic. *Intensive Care Med*. 2020;46:849–850. doi:10.1007/s00134-020-05985-9. PMID: 32199621.

22. Dargent A, Chatelain E, Si-Mohamed S, Simon M, Baudry T, Kreitmann L, Quenot JP, Cour M, Argaud L; the COVIDLUS study group. Lung ultrasound score as a tool to monitor disease progression and detect ventilator-associated pneumonia during COVID-19-associated ARDS. *Intensive Care Med*. 2021;47:849–860. doi:10.1007/s00134-021-06407-1. PMCID: PMC8165084; PMID: 34107394.

23. Vetrugno L, Baciarello M, Bignami E, Bonetti A, Saturno F, Orso D, et al. Lung ultrasound signs and their correlation with clinical symptoms in COVID-19 pregnant women: the “PINK CO” observational study. *Front Med*. 2022;8:768261. doi:10.3389/fmed.2021.768261.

PEDAGOGICAL SCIENCES

RE-EDUCATION - A PSYCHOLOGICAL APPROACH

Ibrahimova A.
Baku city, 300-Complete secondary general education school, Primary school teacher.
DOI: 10.5281/zenodo.18614912

Abstract

The article draws attention to the serious impact of a person's interaction with other people and society in general on his formation as a social being, and shows that the social environment consists of a synthesis of such elements as the existing value system, social and legal norms, the existing state structure, economic relations, the education system, etc. It is emphasized that one of the main tasks ahead in the modern era, when the "techno-democratic-information society" is established, and perhaps the first one, is to raise a useful, responsible and healthy personality for society.

The research paper provides an interpretation of the concept of re-education, presenting an interpretation of the need to comprehensively consider the family environment, societal values, cultural influences, and the child's personal characteristics in this process. The paper also draws attention to the conditions considered essential for achieving good results in the re-education process, specifically emphasizing that it should be implemented with a psychologically justified, empathy-based, and comprehensive approach.

Keywords: society; creative personality; ideal of a perfect person; upbringing; re-education; psychological approach; spiritual ecology; environment; various factors affecting upbringing; conditions for effective re-education.

Relevance of the research topic. In line with the calls of "Industry 4.0", the living conditions, needs and demands of society have changed [11-16] and a system such as the "Techno-democratic-information society" has been formed, which makes people stronger. Logically, the "Education 4.0" system, which is a superstructure phenomenon, has emerged, and the purpose of education has changed.

It is undeniable that the need for improvements and refinements in accordance with the purpose of education at different stages of development of the "Techno-democratic-information society" is an eternal pedagogical problem. Therefore, based on what we have said, we claim the relevance of the research topic "Re-education-psychological approach", which has a special place in the educational process.

Methodological basis of the study. In the process of conducting the study, L. Bertalanfi's "Idea of System Analysis" [9;8] (the idea, the meaning of which is explained as an attempt to study the properties of an object based on the properties of its parts - italics are ours, A.I.) The "System-structural approach", which has been formed as an important branch of dialectics and has risen to the level of its alternative, empirical, empirical-theoretical and theoretical methods of scientific cognition, the internal relationships of the forms of scientific cognition, and various pedagogical and psychological research generalizations were used as a methodological basis.

Interpretation of generalizations based on research materials. Man, on the one hand, is characterized by the characteristics of his relationship with the external environment, and on the other hand, by his unique internal characteristics. Man is not just a physical-biological being, and the environment surrounding him is not just a natural environment. Man, as a social being, also enters into mutual relations with other people and society in general, and these relations have a serious impact on his formation. In this sense, human ecology includes social and spiritual ecology in addition to biological ecology. Human spirituality, on the one hand, although it has genetic foundations, is mainly formed under the influence of the social-spiritual environment. Here, the cultural-spiritual life of society, the culturological aspects of the environment in which a person lives, play an important role [3;405].

The social environment in which a person is formed consists of a synthesis of such elements as the existing value system, social and legal norms, the existing state structure, economic relations, the education system, etc. The cultural and spiritual environment, along with the corresponding attitude of society, is formed under the influence of works of art left over from previous generations, especially fiction and cinema. All this plays an important role in the development of people as specialists and citizens. As in physical and biological ecology, a crisis can occur in social and spiritual ecology. Therefore, preserving the purity of the social and spiritual environment is one of the global problems of the era.

Naturally, today, the struggle for a return to our cultural and spiritual roots, for the determination of national belonging not only in formal terms, but also in terms of content, must also have scientific and theoretical foundations. Especially at a time when television and the press are filled with elements alien to national spirituality, the problem of protecting the spiritual environment is very relevant. Here, it is necessary to proceed from the unity of the process of national self-awareness and the instinct of self-preservation. Although instinct is mainly a psycho-biological concept, we cannot remain indifferent to the social instinct here. Therefore, in order to protect ourselves from alien influences entering our social life from the outside, the instinct of social self-preservation must be formed in our young people today.

One of the most pressing problems in modern times is finding the optimal ratio between national self-isolation and globalization. The globalization process, along with science, technology, and universal values, attempts to infect cultural and spiritual factors that determine national identity. Whether deliberately or unprejudicedly, it makes no difference! In such a situation, it is important to determine what needs to be protected first of all.

As in any work, it is of great importance to know the purpose of education in pedagogical activity. Because when the purpose is clear in advance, its subject builds his work in accordance with that purpose, uses the most appropriate methods and means to achieve this purpose, and achieves the desired results at the end of the activity.

The purpose of education arises from the objective living conditions and needs of society. The goals and tasks set for education in each social structure are determined by the conditions and needs of that structure, by the objective laws of social development. When the living conditions, needs and requirements of society change, the purpose of education also changes accordingly. Even at different stages of development of the same society, socio-political structure, appropriate improvements and clarifications are made to the purpose of education.

It is also true that despite living in different socio-political systems, there is a close affinity between all peoples in their views, including their views on the purpose of education, their desires and aspirations. All peoples of the world try to instill in the growing generation the qualities they highly value and to raise their children as perfect people. Therefore, as experts rightly say, all peoples have created the ideal of the perfect person. However, the specific features of the historical path passed by each people and the social conditions in which they live have had a corresponding impact on the qualities characterizing that ideal, giving rise to certain different shades.[6; 207-208]

Currently, there is a system called "Techno-democratic-information society" that makes people stronger. Providing all members with the necessary and sufficient information and implementing information services at a high level is a special feature of the society in question. Unlike the industrial society, the information society is a more intellectual society and creates conditions for the highly educated, skilled, determined, and comprehensive development of people.

Information society,means the production and use of information, information resources, basic technologies and techniques of the information society, new information - telecommunication technologies and techniques, etc. The main characteristic features of the information society are: mass satisfaction of information needs in society; information economy in society; high level of information demand of society members; high information culture in society, expansion of open information networks for society members; prospects for the formation and development of a single information environment; information security for society members; level of globalization and integration, etc. [11-16].

Members of the “techno-democratic-information society” must have information culture and technological literacy[8], otherwise they will not be able to assert themselves as active and creative members of the society in question.

Despite the fact that we live in a modern era with the rapid development of information and communication technologies, various obstacles appear in children's adaptation to the requirements of the era. There are various factors that cause the emergence of such obstacles, which at the same time lead to the emergence of certain "gaps" in the educational process.

In the modern era of the "techno-democratic-information society", one of the main tasks ahead, perhaps the first, is to cultivate a useful, responsible, and healthy personality for society.

As we know, the concept of personality is broad and multifaceted. Personality does not only mean an educated or well-mannered person. Personality is a set of social, moral, intellectual and psychological qualities of a person formed in society, distinguishing him from others. That is, it reflects a person's worldview, behavior, way of thinking, values, and responsibility.

For these to be formed, education and upbringing must manifest in the form of unity. In order to clarify this point, let us briefly explain the concepts of "education" and "upbringing" separately.

Ancient Turkic sources emphasize that the word " upbringing" belongs to the Turks and is of Turkish origin[1; 374]. There is such a superior feature in the experience of upbringing accumulated in the Eastern world: a person should be consciously educated and improved throughout his life, from birth to death. He should always move along the line of rising to the level of a perfect person[7; 34].

Various scientific interpretations of this concept have been included in scientific sources. In the textbook “Pedagogy”, co-authored by F.N.Ibrahimov and R.L.Huseynzadeh, the concept of “Upbringing” is presented as a process of purposeful, planned and organized formation of moral qualities related to behavior[4;28].

Upbringing is an important indicator of the relationships that a person builds with society in the process of formation. From ancient times to the present day, the concept of upbringing has acted as the main means of guiding a person's behavior, thinking, worldview. The reflection of the ideas of upbringing in oral and written literature confirms the social significance of this process. When defining the theories of Education, Azerbaijani thinkers put the following provisions into their basis: 1.Human nature is contradictory; 2.Since the environment surrounding a person is a field for the struggle between vices and good, human spirituality and behavior are also under the influence of this struggle; 3.Man is in constant psychological development. Through good effects, this process can be changed, refined; 4.All people need to be returned from evil (pure upbringing); 5.The return(pure upbringing) of people from vices is possible and important[7 ;34]. A.X.AZERTAC, F.A.Rustamov has 8 important features of the educational and educational process [10; 285-286] and F.N.Ibrahimov focused on 9 important features [5; 287-288].

Training is the process of acquiring knowledge, skills, and habits, and of training and developing people in a specific field. Through training, individuals acquire new information, gain practical skills, and change their behavior[2].

According to our subjective understanding, the main characteristics of training are: a) it is a purposeful and planned process; b) it is a systematic transfer of knowledge and skills; c) it serves the intellectual and practical development of the individual.

In our opinion, if we take these into account, it will be easier for us to apply training and upbringing in a unified manner and to transform the individual into an individual personality by taking into account the age stages of the individual in this process.

The importance of taking into account the age characteristics of children in education has been commented on in both oral and written literature. Here, making a slight digression, it would be appropriate to turn to the heritage of great philosophers and thinkers such as Plato, Aristotle, N. Ganjavi, M. Fuzuli, YA Komencki, JJ Russo, etc. They classified age periods and also indicated their areas of upbringing and activity. According to Plato, children should be engaged in games in playgrounds under the guidance of state educators at the age of 3-6. At the age of 7-12, children should go to state schools, where they should learn reading, writing, arithmetic, music, and singing. At the age of 12-16, they should go to palist schools, and at the age of 16-18, they should study sciences that have a practical purpose - arithmetic, geometry, and astronomy. They should continue reading and learning until the age of 30.

The ancient Greek philosopher Aristotle went further in this field. For the first time in the history of pedagogy, he divided the age periods into three groups of seven each. 1) The period from birth to 7 years: he called this the vegetative period. Just as it is necessary to take care of a plant, it is important to take care of children who are very delicate during this period; 2) The period from 7 to 14 years: he considered this the animal period; 3) The period from 14 to 21 years, he called it the human period.

Professor P.I. Pidkasistini's views on the age levels of children are also noteworthy. Pidkasistini shows the age levels as follows: 1) early (first) preschool childhood; 2) junior, middle and senior school age; 3) youth. In his opinion, educational institutions are created in accordance with these levels: kindergarten, school, higher education institution, etc.

In general, age periods are defined briefly and concisely as follows: 1) Preschool age period: Infancy period up to 1 year; Infancy period up to 1-3 years; Preschool period up to 3-6 years, 2) Junior school age period - 6-10 years; 3) Adolescence period - 10-11, 14-15 years; 4) Youth period - 15-35 years

Although historical and pedagogical sources present the correct determination of age stages as a key condition for the effectiveness of the educational process, in practice this process does not always produce the expected results.

Some shortcomings in the upbringing process also have a negative impact on the learning process and cause certain deviations in learning. For example, physical violence, bullying, family conflicts, vulgar expressions used between parents, physical force, use of alcoholic beverages, drugs, and psychotropic drugs prohibited for sale by one or both parents, as well as children watching television programs that are not appropriate for their age, using social networks, playing games shared on websites, spending a lot of time on phones, tablets, and computers for useless tasks, and other situations negatively affect the psychological state and learning outcomes of students.

The analysis of the mentioned and similar factors shows that what is observed in the process of upbringing is not accidental and is formed as a result of the interaction of various socio-psychological factors. The process of re-education aims to eliminate negative traits formed in the child's behavior and develop positive qualities. In some scientific sources, the elimination of harmful traits rooted in the child's consciousness or behavior, and the instillation of socially significant qualities in children instead is formulated as re-education[4;29]. N.M.Kazimov and A.Sh.Hashimov write that re-education is the elimination of defects and harmful qualities observed in a person's personality, attitude and behavior[6; 212].

In this process, the family environment, the values of society, cultural influences and the child's personal characteristics should be taken into account in a comprehensive manner. Evaluating not individual factors, but their mutual influence increases the effectiveness of re-education. From this point of view, it is possible to systematize the reasons that create the need for the re-education process as follows: 1. Family environment, economic conditions - family living conditions and financial opportunities; 2. Social environment; a) School environment (collective, classroom conditions); b) Mass media; c) Values and customs of society; d) Friends and peers; e) Cultural environment - books, theater, music; 3. Personal characteristics - temperament, character, inclinations.

Family is the primary and most important environment of upbringing. The child's first social experience, value system such as behavioral models, is formed precisely in the family environment. The nature of family relationships, the parents' upbringing position, and the emotional climate directly affect the development of the child's personality. When there is an environment of understanding, empathy, and emotional security, love, respect, and mutual understanding in family relationships, the upbringing process yields more effective results.

After the family, one of the most influential factors in the formation of a child is the social environment. This includes the peer group, the school staff, teacher-student relationships, the mass media, and the moral values of society. The social environment has a significant impact on the formation of a child's behavioral stereotypes, the assimilation of social roles, and the development of communication skills.

A child goes to school, a new stage begins in his life. A new world is created for the child. Communicating with students, following the rules and regulations of the school, sitting quietly in class, asking permission from the teacher, raising his hand to answer

questions. All this creates a sense of responsibility in the child, the need to be demanding of themselves. Since the first object of perception at school is the teacher, this personality plays a big role in the life of the student. Communication established with the child requires responsibility from the teacher. The teacher stands at the main line of the child's world with his personal example. Sometimes they imitate their teachers with their actions, repeat their speech and actions. As they move from class to class, their feelings increase and change. Feelings of love for the homeland, respect for elders, hard work, etc. manifest themselves. The teacher corrects the mistakes and wrong actions made by young children. Correct relationships with classmates, sharing characteristics, the use of speech etiquette when addressing adults, and other positive qualities are instilled.

Among the age periods, adolescence, due to its pedagogical and psychological characteristics, mostly covers grades V-IX of the school. The adolescence period attracts attention with its pedagogical difficulties, flexibility, and psychological state. The changes that occur during adolescence include communication with peers and adults, and the desire to build a lifestyle that is not in accordance with one's own capabilities, since the teenager considers himself independent. Adolescence the period is called by many scientists “transitional period”, “difficult period”, ”turning period”, and even “crisis period”. The emergence of these names is taken for granted. A teenager is the most difficult object for both a parent and a teacher, and for himself. They consider adolescence to be “the path to gaining a position in society.”

During this period, children are more inclined to perform actions that are characteristic of adults. Teenagers do not like guardianship, they do not want to be criticized. That is why they often use the words “I know what I am doing”, “don’t interfere in my business”, “I am not a child anymore”. Teenagers expect that adults will understand them, change their previous attitude, respect them, and not allow situations that will violate their dignity.

Experience shows that a teenager's desire to assert himself as an independent personality, emotional instability and changes in social relationships sometimes lead to violations of behavioral norms. These situations can become even more serious if the family and school do not provide proper guidance. It is in such a situation that the process of re-education becomes necessary. Re-education serves to eliminate negative tendencies in the teenager's behavior and thinking, and to re-form a system of values appropriate to society, taking into account his psychological characteristics and age level.

One of the factors influencing the upbringing of children is mass media. The Internet, which seemed inaccessible at the time, has become very simple and covers a large area in our modern era, while at the same time enslaving people. Today, we receive news in seconds that we once waited for months by letter.

Becoming enlightened, increasing their worldview and knowledge, transferring and sharing the information they receive to other sources, electronic libraries, online lessons, distance learning, encyclopedic information, various educational websites, and learning various foreign languages create conditions for the further improvement of the young generation and their growth in accordance with society and its requirements.

However, it should also be noted that sometimes mass media, misinformation, and news spread on social networks create wrong opinions and positions in people. Therefore, when using mass media, it is necessary to use verified opinions and websites.

The cultural environment is considered one of the important factors in the moral and aesthetic education of children. Cultural tools such as books, theater, and music have a significant impact on the expansion of a child's worldview, emotional development, and the formation of a value system. These tools create conditions for the development of correct behavioral norms, aesthetic taste, and creative thinking in children.

Books play a key role in a child's intellectual development and moral upbringing. The habit of reading increases children's thinking ability, forms speech culture, and helps to assimilate positive behavioral patterns. Reading works with moral and educational content leads to the formation of qualities such as kindness, compassion, honesty, and responsibility in children.

Theater art influences the development of empathy in children, the formation of the ability to evaluate events and draw conclusions. The images and life events presented on stage teach children to distinguish between good and evil, to understand the rules of social behavior. Theater performances also form children's aesthetic taste and strengthen their cultural behavioral habits.

Music plays a special role in the emotional and psychological development of children. Through music, children develop inner harmony, control of emotions, and aesthetic perception. National and classical musical samples strengthen children's sense of national identity, spiritual connection, and respect for cultural heritage. Regular contact with music plays a calming and regulating role in the upbringing of a child. These cultural tools support the educational activities of the family and school, serving the harmonious development of personality.

In addition to the social and cultural environment, a child's personal characteristics also play an important role in their upbringing. Temperament, character, and individual tendencies directly affect a child's behavior, communication style, and how they perceive educational influences. Taking these characteristics into account allows for a more purposeful and effective upbringing process.

Temperament reflects the natural characteristics of a child's psychological activity and is mainly characterized by the speed of emotional reactions, the intensity of activity and the stability of behavior. Children with different temperament types may react differently to the same educational influences. Therefore, choosing an approach that is appropriate for the child's temperament in the educational process is important in terms of maintaining his emotional balance and promoting positive behavior.

Taking into account personal characteristics, especially temperament and character, is the basis of an individual approach to re-education. The psychological approach involves choosing upbringing methods that

are appropriate for the child's temperament, properly managing his emotional reactions, and replacing negative behaviors by developing individual inclinations.

In order to achieve good results in the process of re-education, the following conditions must be met: creating conditions for cooperation in the child, setting a high moral example for him; studying the causes that give rise to harmful qualities in the child; identifying and applying the most optimal means to eliminate these causes; making extensive use of a system of stimulating methods in the education process, especially methods of encouragement, example and demand; instilling confidence in the child's own strength and activity; increasing control over educational work; basing oneself on the known principles of education, including the principles of optimism, respect and demandingness; not allowing authoritarianism, but resorting to administrative, disciplinary measures if it is impossible to do without them, etc.

Of course, every teacher must use these conditions creatively in their re-education work.

Conclusion. 1. The re-education process should be carried out not only with control and punishment mechanisms, but with a psychologically justified, empathy-based and comprehensive approach; 2. A psychological approach based on the above factors reduces the child's internal resistance in the re-education process, increases self-confidence and ensures the sustainability of behavioral changes.

References

1. Abbasov A.N., Məmmədzadə R.R., Məmmədli, L.A. Pedaqogika: müntəxəbat(Ali təhsil müəssisələri üçün dərs vəsaiti). Bakı: “Mütərcim”, 2021, 608s.

2. Əlizadə Ə.Ə. Müasir Azərbaycan məktəbinin psixoloji problemləri. Bakı: “Pedaqogika”, 2004. 432s.

3. Xəlilov S.S. Təhsil, təlim, tərbiyə. Bakı, “Azərbaycan Universiteti” nəşriyyatı, 2005, 650 s.

4. İbrahimov F.N., Hüseynzadə R.L. Pedaqogika(Dərslik). 2 cilddə, I cild. Bakı: “Mütərcim”, 2013, 708 s.

5. İbrahimov F.N. Ümumi pedaqogika (Dərs vəsaiti). Bakı: “Mütərcim”, 2014, 864s.

6. Kazımov N.M., Həşimov Ə.Ş. Pedaqogika(Dərslik). Bakı: “Maarif” nəşriyyatı, 1996, 416 s.

7. Qaralov Z.İ. Tərbiyə (prinsiplər, məzmun, metodika). 3 cilddə, I cild. Bakı: “Pedaqogika”,2003, 268 s.

8. Məmmədova Elmira.Texnoloji savadlılıq: Rəqəmsal dünyada uğurun açarı (tr.linkedin.com/posts/elmira-mammadova-01807722).

9. Mirzəcanzadə A.X. İxtisasa giriş(Heft və qaz profilli ali məktəblər üçün dərs vəsaiti), Bakı, BDU nəşriyyatı, 1990, 368s.

10. Paşayev Ə.X., Rüstəmov F.A. Pedaqogika, Yeni kurs(Pedaqoji universitetlərin və ali pedaqoji məktəblərin tələbələri üçün dərs vəsaiti). Bakı: “Elm və Təhsil”, 2017, 464 s.

11. K. Challenges and Opportunities for Education in the Fourth İndustrial Revolution // African Journal of Public Affairs, 2019, Vol 11, №3, pp.78-94.

12. Sari L., Arif S. The Roles of Digital Literacy, Technology Literacy, and Human Literacy to Encourage Work Readiness of Accounting Education Students in the Fourth İndustrial Revolution Era// International Conference on Economics, Education, Business and Accounting, 2019.

13. Priya S. Digital Revolution of Education 4.0// International Journal of Engineering and Advanced Technology (İJEAT), 2019, Vol9, №2, pp.58-64.

14. Mascheroni G., Olafsson K. The mobil internet: Access, use, opportunities and dividies among European children// New media and Society, 2016, Vol 18, №8, pp.57-79.

15. Ercan Ö. Egitimde Yeni Yönelimlerin Degerlendirilmesi ve Egitim 4.0//Universite Araşdırmaları Dergisi, 2018, Vol 1, №1, pp.25-30;

16. Ling Li. Educattion supply shain in the era of İndustry 4.0// System Research and Behavioral Science. 2020, Vol 37, №4, pp.579-592.

THE "EDUCATION→ENGINEERING←ARTIFICIAL INTELLIGENCE" PARADIGM OF PUBLIC ACTIVITY IN THE "TECHNO-DEMOCRATIC-INFORMATION SOCIETY"

Ibrahimov F.
Professor of the Sheki branch of Azerbaijan State Pedagogical University, Sheki, Azerbaijan
Ibrahimova A.
Baku city, 300-Complete secondary general education school, Primary school teacher
DOI: 10.5281/zenodo.18614923

Abstract

The research shows that intellectual and creative activity of everyone living in the "Techno-democratic-information society" becomes a paramount requirement, and for this, it is desirable for every member of this society to rise to the level of a subject of intellectual skills, they must have information culture and technological literacy.

The research work clarifies the main reasons for the reforms carried out in the education system and its implementation system in connection with the challenges of the Fourth Industrial Revolution, and expresses the attitude towards the logic of the existence of subsystems such as STEM and STEAM (active/interactive or learner-centered) education, based on the paradigm of "education→engineering←artificial intelligence" of social activity in the "Techno-democratic-information society" and the schematic description of the path of implementation expressed as "S-S".

Finally, this work highlights the irreplaceable importance of artificial intelligence in the context of the Fourth Industrial Revolution and digital technology, and considers artificial intelligence as a strategic technology central to Industry 4.0; It is emphasized that the impact of artificial intelligence on the future will depend on how we manage the technology and how we adapt to this change as a society, and a concise explanation of the rather wide range of its engineering applications is given.

Keywords: Education; Technology; İnformation society; İnformation culture; Technological literacy; Artificial intelligence; Engineering applications; Paradigm of social activity.

Introduction

Everyone living in the currently formed "Techno-democratic-information society" must perform intellectual, creative activities. For this, a person must rise to the level of a subject of intellectual skills. The importance of artificial intelligence in the context of the IV industrial revolution and digital technology is irreplaceable. Artificial intelligence is selected as a strategic technology that occupies a central place in Industry 4.0.– The impact of artificial intelligence on society, education, health and quality of life, social interaction and social behavior, changing the economic structure, ethical and legal issues, human-machine collaboration, data-driven learning and prediction systems, deep learning - a branch of machine learning, the use of multilayer artificial neural networks, and so on seems logical.

The impact of artificial intelligence on the future will depend on how we manage technology and how we adapt to this change as a society. It is undeniable that education has an important role in preparing society for this process, and from the point of view of the realization of the aforementioned preparation, a learner-centered system based on the "education → social activity ← artificial intelligence" paradigm should take its place as a superstructure phenomenon, and the theoretical and technological foundations of the optimal ways of realizing such a system should be clear. This problem makes the solution of cognitive issues formed by focusing on various types of social activity relevant. "Determining the nature of education based on the "education → engineering ← artificial intelligence" paradigm of social activity in a techno-democratic-information society" has a special place among the cognitive issues that need to be solved.

Purpose of the study: The aim is to determine the directions for defining the nature of education within the "techno-democratic–information society," based on the paradigm of "education → engineering ← artificial intelligence." In this context, it is taken into account that the idea itself represents a fundamental value; the human world of activity has always been grounded in ideas; and every individual advances step by step by verifying the adequacy of their actions with the idea they consider acceptable as the outcome of their activity.

Methodological basis of the research: In the process of conducting the research, L. Bertalanfi's "Idea of System Analysis" [3;8] was used (the idea, which is interpreted as an attempt to study the properties of an object based on the properties of its parts - italics are ours - F.I.; S.I.; G.A.) The "System-structural approach", which has been formed as an important branch of dialectics and has risen to the level of its alternative, empirical, empirical-theoretical and theoretical methods of scientific cognition, the internal relationships of the forms of scientific cognition, and various pedagogical and psychological research generalizations were used as a methodological basis.

Interpretation of generalizations from research materials: Throughout history, radical changes in industry and production processes have been described as industrial revolutions. These revolutions have significantly transformed production methods, the structure of the workforce, and the social system through technological advancements.

The First Industrial Revolution (late 18th and early 19th centuries) was characterized by the discovery of steam power and the use of mechanical production machinery. During this period, the mechanization of textile and metallurgical production led to a significant increase in production capacity and accelerated the migration of rural communities to industrial areas. The use of mechanical power reduced the complexity of production and created the basis for mass production.

The Second Industrial Revolution (late 19th century–early 21st century) was defined by electricity, steelmaking, and mass production technologies. The distribution of electricity enabled continuous production lines in factories and standardized "production lines" (flows). Henry Ford's assembly lines enabled mass production and ultimately reduced production costs. During this period, engineering practices, production management, and organizational structures achieved a certain degree of modernity.

The third industrial revolution (dating back to the mid-20th century) was characterized by the rise of computers, electronic devices, and automation technologies. Computer-aided design (CAD), robotic production lines, and control systems increased the efficiency of production processes and reduced human intervention. During this period, information technology, data processing, and automated control systems enabled faster and more accurate results in engineering and scientific research. Industry 3.0 also helped to make production and logistics networks more integrated and flexible on a global scale.

The current fourth industrial revolution (Industry 4.0) is characterized as an era of integration of physical, digital and biological systems. The Fourth Industrial Revolution has different implications for different areas of our lives. The Fourth Industrial Revolution requires the simultaneous and comprehensive use of technologies such as cyber-physical systems, the Internet of Things (IoT), big data analytics, cloud computing and artificial intelligence. Industry 4.0 is changing not only production processes, but also scientific research methods, economic structures and public order.

This stage of development has created new opportunities for education that bring values specific to civilization (the use of different technologies such as IoT, 3D printing, quantum computing, artificial intelligence, etc. has led to a more effective transfer of information)[20; 78-94].

As can be seen, the process of civilization has been continuously formed in response to the calls of the "Industrial Revolutions", systems of socio-economic relations have been established on the basis of dialectical conditioning of one another (logical expectation), and superstructures based on the aforementioned bases have been formed. Currently, there is a system-basis such as the "technodemocratic information society" that makes people stronger.

"Information society" means the production and use of information, information resources, basic technologies and techniques of the information society, new information - telecommunication technologies and techniques, etc. The main characteristic features of the information society are: meeting the mass information needs of society; information economy in society; high level of information demand of society members; high information culture in society, expansion of open information networks for society members; prospects for the formation and development of a single information environment; information security for society members; level of globalization and integration, etc. In general, the provision of all members with sufficient information in an appropriate manner and the implementation of information services at a high level are the specific features of the society in question. The information society, unlike the industrial society, is a more intellectual society and creates conditions for the highly educated, skilled, determined, and comprehensive development of people.

The main features of the "Technodemocratic information society" established in the modern world suggest that the people represented in this society must have information culture and technological literacy, otherwise they will not be able to assert themselves as active and creative members of the society in question.

By the way, let us note that in the concept of "Information culture" we mean the acquisition of a system of knowledge, intellectual skills and habits necessary for a person to adapt to the information society. It is undeniable that the role of the computer network in the formation of information culture is great. Information culture: is the ability to use information resources and information communication tools of society; is the application of advanced achievements in the field of informatization and the development of information technology tools in society; is the ability to obtain and transmit information using modern technical means and methods, computer technologies.

Technological literacy– the ability of people to use various digital technologies, analyze data, and operate safely in a digital environment. “This skill is not limited to using a computer and the internet, but also includes: 1) Adhering to digital safety and cybersecurity rules; 2) Working with artificial intelligence and automation; 3) Digital analytics and data processing skills; 4) Using cloud technologies; 5) Quickly adapting to new technologies”[9] Technological literacy includes the ability to use information and communication technologies.

Modern education, which is currently establishedIt is one of the superstructures of the existing base as a “technodemocratic information society”. It is undeniable that education, which is a process of sharing human experience, has developed in stages as a product of social practice (and especially pedagogical science), incorporating the characteristics of industrial revolutions. In the era of the IV industrial revolution, an education system that can form a creative, innovative and globally competitive generation is required, and currently the impact of the aforementioned revolution on the educational process, the issue of “education of the future” is being discussed on various platforms and the necessary steps are being taken accordingly.[17], [18; 92-97].– –

Digital education, improves people’s ability to participate independently in modern social life. In addition, the reality of digital education and the digital revolution requires fundamental changes in the forms

and methods of moral education, leading to the emergence of digital skills as the most important competence [22;58-64]. The development of digital skills is essential to ensure that they can safely and effectively interact with digital technologies in the future. Education systems need to take a comprehensive and integrated approach, supporting all learners to develop the skills to be active and ethical users of digital technologies. [23; 57-79]

It is necessary to distinguish two main reasons for the reforms carried out in the education system and its implementation system in connection with the challenges of the Fourth Industrial Revolution. The first is the training of a workforce with knowledge (information) and skills in accordance with the needs of a rapidly changing global economy, and the second is the establishment of an education and implementation system that can bring to the fore the productive forces (labor force) necessary for the development of an adequate information society during the industrial revolution. [15;288]

Despite what has been said, the basis of public activity in the "Technodemocratic information society" is "education".−−→engineering artificial intelligence" paradigm is set and←The schematic description of the implementation path is that education, expressed as "SS" (active/interactive or learner-centered), has subsystems such as STEM and STEAM.

The STEM subsystem has been applied in the education system of a number of countries since the second half of the last century. In this system, mathematics, technology, engineering and natural sciences are implemented in interaction (together). The main goal of the application of STEM is to form and develop “XXI century 4C skills” in schoolchildren. The inclusion of the aforementioned system in education creates such a dominant environment that schoolchildren develop their creativity, teamwork skills, logical thinking, and problem-solving skills by applying the various information they learn in mathematics and natural sciences to various problems they encounter in their daily lives and in various projects. [2;22-23] It is undeniable that Creativity is considered the most basic skill that distinguishes humans from other living beings, and the application of STEM creates conditions for developing creative skills in learners during teaching. Learners who participate in the process that includes this system as the main party have the opportunity to observe the results obtained during small-scale experiments, investigate the errors that arise, and rebuild the experiments. It is precisely in such an organized environment that the information obtained is more permanent, since the learning process is based on discussion in the form of groups, learners express their attitude to the work of their teammates, justify their arguments. The organizational form chosen adequately for the process that includes STEM usually ends with a report or presentation on the results of the experiment or project. Since the process that includes STEM is more project-based and organized in a group work format, group members also perform a leadership function, lead the group/project, and make decisions. As a result, leadership skills are developed in learners. The main goal of the training process that transforms STEM as a subsystem is to prepare students for the future work environment. All of the skills mentioned above prepare students for positions they will hold as effective human resources. [13]

Included in the active/interactive learning process Although the STEAM subsystem differs from STEM in only one direction - A-Art (art), the advantages of training based on the STEAM model are great. Thus, this system:1. Stimulates creative thinking; 2. Offers meaningful collaboration; 3. Strengthens critical thinking; 4. Provides a unique way to solve problems (students are forced to use methods that lead to unusual solutions to solve existing problems); 5. Provides practical learning experience.

The process involving STEAM is more creative and fun. Based on logical grounds, it can be hoped that learners who are influenced by the cognitive or technological process involving this subsystem will be able to apply innovations in the future. In the process of this nature, they use various fields: mathematics and other exact sciences, engineering, design, digital devices and technologies. STEAM is a system with a universal practical orientation, relatively independent or dominant, allowing students to perform any complex task, in which students put their knowledge into practice. The cognitive or technological process that includes this subsystem is useful and necessary for every modern school. The unique place of STEAM in the educational substrate provides students with the opportunity to learn creatively using 21st century skills such as problem solving. It is worth emphasizing that “The 4C skills of the 21st century are collaboration, creativity, critical thinking, and communication. They are essential components of individual success in a rapidly changing workforce and society.” [12]

The transformative process of STEAM is to integrate subjects into a unified learning model based on real-world applications, rather than teaching them in isolation. ThisIt is an integrated “enabler” of learning that requires a connection between standards, assessments, and lesson design/implementation, andIt produces results in terms of positive self-denial in students who take deliberate risks, engage in experiential learning, persist in problem solving, embrace collaboration, and work in a creative process: these are the innovators, educators, leaders, and learners of the 21st century!

Based on scientific research, we conclude that those who are educated in a "sharing process" based on the combination of Science, Technology, Engineering, Art, and Mathematics will contribute to development by shaping themselves as creative, innovative, and enterprising individuals of the future with special abilities and talents.[6]

The application of this system of implementing education leads learners to the following conclusion: Science helps people understand the laws of the world; engineering and technology help people change the world according to social needs; art helps people enrich the world in a good way; and mathematics gives people the structural analysis to develop and apply the methods and analysis tools of science, engineering, art, and technology.

It must be concluded that the process in question is related to the "why and how", it is a process of application, a system that allows for the creation of meaning. Here, the idea is based on research, a critical approach, and deep questioning.[7]

In the system that includes STEAM, project-based learning (PBL), interdisciplinary integration and cross-disciplinary learning, inquiry-based learning, design-based learning, game-based learning, analogy-based learning, mobile-based learning, and making small changes, making-doing learning methods are used more. 3D design modeling (Tinkercad), 3D printing, block programming on the micro bit platform, and implementing projects with sensors (Coding) are the main tools that are important during the project.−[6].

In this systemBasically, project-based learning, problem-based learning as the main teaching (learning) approach, aims to guide learners through cooperation and experience, complete the subject of the project, and solve problems encountered in life. As a kind of traditional education mode, the STEAM substrate system has the potential to reduce the gap between students' existing knowledge and skills and professional knowledge and skills and increase their competitiveness.

Digital technologies, becoming a part of our lives, are bringing both structural and power changes to the education system. Today, people with strong disciplinary knowledge, analytical, creative and critical thinking skills are in demand in all fields. Based on logic, one can believe in the effectiveness of the knowledge and skills that this system provides to learners, their professional development and future life.[4;145]

Education that includes STEAM can help students enrich their learning experiences at a lower cost, which is essential for students to succeed in a rapidly changing world, and it teaches students to evaluate their personal interests, life opportunities and career development, current and potential contexts, and to understand the future of their careers, professional interests and develop their knowledge and skills well. Students who are covered by education based on the mentioned system and teachers who have an organizational and management function and facilitate this process build more real-life relationships. This is desirable. Because school is not a place where students go simply to learn. Students should have the following conclusion: “We are always learning, we are always growing, we are always experimenting.”

In order for students to demonstrate their skills and abilities in new areas emerging under the influence of the Fourth Industrial Revolution, it is necessary to implement fundamental changes in technology and the curricula of the subjects taught. By reviewing the curricula of the subjects formed on the basis of chemistry, biology, physics, etc., which are considered "basic sciences" in the new curricula, more attention should be paid to the teaching of computer science subjects, which play a key role in the formation of the Fourth Industrial Revolution literacy. Naturally, more attention should be paid to the teaching of the subjects in question. [26; 432-466]

Due to the rapid development of technology, the knowledge and skills that students learn during their education become obsolete by the time they graduate. In order to help develop and shape the use of today's fastest-growing technologies in scientific and technical education, it is necessary to educate students and prepare them for the digital environment. Adapting to a rapidly changing environment requires that students maintain contact with educational institutions even after graduation. and will provide both workers with updated skills and young learners (and faculty) with a new direction relevant to the rapidly changing realities of the industrial and corporate sectors.[24; 25-30], [25; 579-592]

It is undeniable that there is a specificity in the calls of each industrial revolution. This is manifested against the background of global changes taking place in the world, and at the same time it determines the existence of new shades in information culture and in the content of technological literacy. At different stages of world history, humanity has faced serious changes and achieved results with the reforms carried out. Against the background of industrial revolutions, educational program developers had to seek answers to the following fundamental questions: 1) What knowledge, skills and values should be reflected in educational programs?; 2) Will these knowledge, skills, values and competencies form the necessary life skills in learners?; 3) How can the process of implementing education be made relevant and interesting for learners?; 4) How can assessment (an integral part of the process of implementing education) be made more productive and effective?

In our modern era, parameters such as relevance, practicality, effectiveness, and sustainability are the indicators of the quality of an educational program, while the indicators of its success are the quality of acquisition by learners and the extent to which learners can effectively use what they have acquired for their personal, social, cognitive, psychological, and emotional development. [5; 5]

By the way, UNESCO has the following criteria for a quality education program. An education program should: have clear objectives; meet today's requirements; be relevant to the current and future lives, experiences, desires and aspirations of learners; aim to build a prosperous future for learners in social and economic terms, taking into account the history and culture of the country in which they live; be fair and inclusive (taking into account the individuality, individual needs of learners, etc.); be learner-centered (takes into account the needs of the learner, is appropriate to the learner's age, helps in personal development and the formation of life skills, and does not overload learners); be open and flexible (integrates emerging innovations into the content); be consistent and relevant.[5; 5]

The Fourth Industrial Revolution has had an impact on the education system as well as on the socio-economic spheres. In line with the industrial revolutions, "education, which is a process of sharing the experience of understanding and transformation", has developed in stages (including the specific characteristics of industrial revolutions). It is worth emphasizing that the expected paradigmatic changes in the education

system and the implementation of global education reform have been further accelerated by the influence of the Fourth Industrial Revolution[27; 147-171].

In connection with Industry 4.0, we would not be wrong to say that "innovation has begun to dominate education systems". In our opinion, educational institutions will have to see innovation not only as a means of ensuring increased global competitiveness under the influence of globalization, but also as one of the main parts of the education system. In accordance with the requirements of the times, the teaching of new technologies will be accepted as one of the main needs on a logical basis. "Lifelong learning" will be the main motto of the education system. Naturally, the content of education should also take into account the skills of the 21st century: in addition to knowledge, the development of abilities and skills such as complex problem solving, critical thinking, creativity, leadership, digital literacy, emotional intelligence, global citizenship, cooperation, discussion, judgment and decision-making will also be accepted as the main learning outcomes.

Education 4.0 should serve to form the skills (intellectual skills) to use new technologies that help learners develop in accordance with changes in society. It should form knowledge and skills that learners can use throughout their lives, not just reading and writing. Thus, the system should respond to changes in the social and economic environment to meet the needs of human capital. Education 4.0 aims to prepare individuals to be creative and innovative. Education should adapt to the environment in which learners live and provide them with a secure and successful future. This new system uses "smart" school management systems, learning management programs, communication tools, and teaching and learning tools.[19; 238-254]

In the Education 4.0 approach, going beyond constructivist education systems and Bloom's taxonomy, intellectual It has been determined that an environment-based learning process will be applied that focuses on the formation and development of skills: 1) 3Rs (Recalling, Relating, Refining) that regulate understanding; 2) 3I (Inquiring, Interacting, Interpreting) that encourages research; 3) 3Ps (Participating, Processing, Presenting) that are based on drawing conclusions.[28; 92-98], [29; 40-45]

Education 4.0, which provides an effective environment for the formation of intellectual skills, has the following characteristics: 1) Learning regardless of time and place (lifelong learning, e-learning, etc.); 2) The opportunity to receive personalized education according to the skills and abilities of students; 3) Taking into account the suggestions of students when preparing the curriculum; 4) Predominance of project-based learning; 5) Formation of students' ability to conduct analysis on large-scale data (Big Data); 6) Assessment of students' knowledge in the process of applying them to projects; 7) Becoming a part of the educational system of emerging new technologies, etc. [17-18]

In the era of the Fourth Industrial Revolution, "smart" educational tools and resources should enable individuals to acquire more advanced experience, knowledge, and skills, and to reveal their innovative perspectives.

In the context of the fourth industrial revolution and digital technology, the importance of artificial intelligence is irreplaceable. Artificial intelligence is highlighted as a strategic technology that occupies a central place in Industry 4.0. Big data and machine learning algorithms allow for immediate analysis of data on production lines, prediction of possible failures and automation of decision-making processes. This provides a decisive advantage, especially for smart factories, autonomous logistics systems and special production models. Smart grids in the electricity and energy industry; On the other hand, production planning, logistics management and process optimization in industrial engineering are becoming more effective thanks to artificial intelligence-based solutions.

■Artificial intelligence has a fairly wide range of applications in engineering. In mechanical engineering, artificial intelligence is widely used for optimizing production processes, predicting failures and maintenance, and controlling robotic systems. It is worth emphasizing that:

* Prediction: Equipment failures are predicted in advance using sensor data and machine learning algorithms. This reduces production downtime and reduces maintenance costs.

* Robotics and automation: Artificial intelligence algorithms in autonomous robotic systems improve motion planning, task optimization, and human-robot interaction.

* Design optimization: Artificial intelligence allows you to find efficient solutions by using complex engineering in modeling and optimization processes.

■Electrical and electronics greatly benefit from the application of artificial intelligence in energy management, circuits, and smart systems.

■Smart Grids: AI optimizes electricity generation and distribution, providing demand forecasting and fault detection.

■Unattended systems: electric cars, drones, and other autonomous devices can perform perimeter sensing, route optimization, and safe navigation thanks to artificial intelligence algorithms.

■Circuit and system design: Performance analysis and electronic circuit optimization can be performed with machine learning, shortening design time.

■Artificial intelligence is used in engineering to monitor the condition of buildings, analyze risks, and develop sustainable projects.

■Structural health monitoring: sensor data is analyzed using machine learning algorithms to determine the longevity of the structure and possible damage.

■Risk analysis and disaster management: artificial intelligence models help to secure building structures by predicting the risks of earthquakes, floods, and other natural disasters.

■Smart city applications: urban life is optimized using artificial intelligence-based systems for traffic management, energy efficiency, and infrastructure planning.

■ Industrial engineering actively uses artificial intelligence in planning production processes, managing logistics, and optimizing processes.

* Production planning: Artificial intelligence algorithms allow for optimal decisions in raw material supply, production lines, and workforce planning in July.

* Logistics and supply chain management: inventory optimization, route planning, and distribution processes become more efficient with machine learning.

* Process optimization: the efficiency of production and operational processes increases, costs are reduced, and product quality is improved.

The use of artificial intelligence in engineering not only increases the efficiency of production and design processes, but also enhances the creative and analytical thinking abilities of engineers. In addition, thanks to interdisciplinary integration, artificial intelligence allows developing innovative solutions in various engineering fields. In this context, artificial intelligence is positioned as an integral part of modern engineering.

There is no denying that artificial intelligence is playing an increasingly important role in scientific research and engineering, and this is an ongoing process. Complex data sets, experimental modeling, and interdisciplinary research are becoming faster, more accurate, and more efficient thanks to artificial intelligence algorithms.

In general, the impact of AI on the future will depend on how we manage the technology and how we adapt to this change as a society. In our opinion, it seems logical that AI will have an impact on society, education, health and quality of life, social interaction and social behavior, changing economic structures, ethical and legal issues, human-machine collaboration, data-driven learning and prediction systems, deep learning - a branch of machine learning, the use of multilayer artificial neural networks, and so on.

It can be said that artificial intelligence is based on mathematical modeling, data analysis, and algorithmic learning. Machine learning, deep learning, and data-driven models allow for the effective use of artificial intelligence in modern engineering and scientific research. We believe that these are the necessary infrastructure for the transition to engineering and scientific applications.

Scientific novelty of the research: The idea of education based on the paradigm of "education → engineering ← artificial intelligence" of social activity in the "techno-democratic-information society" has been brought to the attention of the scientific community.

The theoretical significance of the study: "This research has a specific function in line with the call to direct further scientific and scientific-pedagogical activity on a broad study of theoretical and practical ways to solve the problem of "creating conditions for sustainability for the future development of society."

Practical Significance of the Study: The practical significance of the study lies in the fact that, in real pedagogical practice, practitioners have gained the opportunity to utilize the idea of education based on the paradigm of societal activity in the "techno-democratic–information society" as "education → engineering ← artificial intelligence" in their professional activities.

Conclusion:

1. In the "techno-democratic–information society," it becomes a priority requirement for every individual to engage in intellectual and creative activities, and for this, it is necessary for each member of this society to reach the level of a subject of intellectual skills.
2. In a society formed in accordance with the challenges of the Fourth Industrial Revolution, it is a desirable quality for each member to possess information literacy and technological competence.
3. The education system adequate to the "techno-democratic–information society" has found its place in scientific literature and pedagogical practice under the term "Education 4.0" and has been interpreted as a higher-level structure based on logical principles.
4. "Education 4.0," which provides an effective environment for the formation of intellectual skills, has specific characteristics.
5. The study has determined ideas regarding the directions for defining the nature of education based on the paradigm of societal activity in the "techno-democratic–information society" as "education → engineering ← artificial intelligence."
6. In the context of the Fourth Industrial Revolution and digital technology, the significance of artificial intelligence is indispensable; artificial intelligence is selected as a strategic technology occupying a central position in Industry 4.0.
7. The impact of artificial intelligence on the future will depend on how we manage technology and how society as a whole adapts to this change.
8. The use of artificial intelligence in the field of engineering not only increases the efficiency of production and design processes but also enhances the creative and analytical thinking capabilities of engineers.

References

1. Alizadeh, A. A. (2004). *Psychological problems of the modern Azerbaijani school*. Baku: Pedagogika.
2. Ibrahimov, F. N. (2018). *Philosophy, didactics, and implementation technology of mathematical education in secondary schools*. Baku: Mütərcim.
3. Mirzajanzadeh, A. X. (1990). *Introduction to the specialty (Textbook for oil and gas profile higher schools)*. Baku: BSU Publishing House.
4. Mehrabov, A. O. (2010). *Conceptual problems of modern education*. Baku: Mütərcim.
5. Maximum Education Center. (2024). *Methodology and pedagogy (A manual based on the updated framework document)*. Baku: Maximum Education Center.
6. Muallim. (n.d.). *Müəllim xəbərləri*. https://www.muallim.edu.az/news.php?id=12593
7. STEMART. (n.d.). *STEM və STEAM haqqında*. https://www.stemart.az/az/newsd/9-stem-steam-haqqinda-bilmak-istadiklariniz
8. Huseynzade, R. L., & Ibrahimov, F. N. (2013). *Pedagogy* (Vols. 1–2). Baku: Mütərcim.
9. Mammadova, E. (n.d.). *Technological literacy: The key to success in the digital world*. LinkedIn. https://tr.linkedin.com/posts/elmira-mammadova-01807722

10. Feyziyev, J. A., Ibrahimov, F. N., & Bediyev, S. R. (2011). *Didactics (Textbook)*. Baku: Mütərcim.

11. Petrovsky, A. V. (Ed.). (1977). *General psychology* (2nd ed., Trans.). Baku: Maarif.

12. Təhsil.biz. (n.d.). *STEAM gələcəyin təhsil modelidir*. https://tehsil.biz/news/az/3362/STEAM-glcyin-thsil-modelidir

13. 525.az. (n.d.). *Xəbərlər*. https://525.az/?name=xeber&news_id=132946

14. Veysova, Z. (2013). *Application of new subject curricula at the general secondary education level*. Baku: Inkishaf Scientific Center.

15. Rasulov, R. A., Ibrahimov, F. N., & Abdullayeva, G. A. (2022). *Sheki branch of the Azerbaijan State University of Physical Education in 30 years: Successes, prospects*. Baku: Mütərcim.

16. Schwab, K. (2016). *The fourth industrial revolution*. Geneva, Switzerland: World Economic Forum.

17. World Economic Forum. (2016). *New vision for education: Fostering social and emotional learning through technology*. http://www3.weforum.org/docs/WEF_New_Vision_for_Education.pdf

18. Vichian, P. (2016). Education 4.0: New challenge of learning. *St. Theresa Journal of Humanities and Social Sciences, 2*(2), 92–97.

19. Wilkesmann, M., & Wilkesmann, U. (2018). Industry 4.0 – Organizing routines or innovations? *VINE Journal of Information and Knowledge Management Systems, 48*(2), 238–254.

20. Hristian, K. (2019). Challenges and opportunities for education in the Fourth Industrial Revolution. *African Journal of Public Affairs, 11*(3), 78–94.

21. Sari, L., & Arif, S. (2019). The roles of digital literacy, technology literacy, and human literacy to encourage work readiness of accounting education students in the Fourth Industrial Revolution era. In *International Conference on Economics, Education, Business and Accounting*.

22. Priya, S. (2019). Digital revolution of Education 4.0. *International Journal of Engineering and Advanced Technology, 9*(2), 58–64.

23. Mascheroni, G., & Olafsson, K. (2016). The mobile internet: Access, use, opportunities and divides among European children. *New Media & Society, 18*(8), 57–79.

24. Ercan, Ö. (2018). Development of new directions in education and Education 4.0. *University Research Journal, 1*(1), 25–30.

25. Li, L. (2020). Education supply chain in the era of Industry 4.0. *Systems Research and Behavioral Science, 37*(4), 579–592.

26. Fatih, D., Elif, I., & Nurdan, K. (2019). Educational program 4.0 from the means of realizing the targeted transformation in higher education. *Bayburt Faculty of Education Journal, 14*(8), 432–466.

27. Abdullah, D. (2018). Changing education training paradigms from Industrial 4.0 to Education 4.0. In *International Congress on Social Sciences (İNCSOS 2018 Quds)* (Vol. 13, No. 15, pp. 147–171).

28. Hussin, A. (2017). Education 4.0 made simple: Ideas for teaching. *International Journal of Education and Literacy Studies, 6*(3), 92–98.

29. Dario, A., Alessandro, C., Marta, F., & Elpido, R. (2019). Smart education in the context of Industry 4.0. In *IEEE Global Engineering Education Conference (EDUCON)* (pp. 40–45). IEEE.

РОЛЬ ВОКАЛА В ПРОФЕССИОНАЛЬНОЙ ПОДГОТОВКЕ СТУДЕНТОВ МУЗЫКАЛЬНОЙ ДРАМЫ

Жумагазин Ж.Р.
Преподаватель кафедры «Сольное пение»
Казахской национальной академии искусств имени Т. Жургенова
Республика Казахстан, г. Алматы

THE ROLE OF VOCAL TRAINING IN THE PROFESSIONAL DEVELOPMENT OF MUSICAL DRAMA STUDENTS

Zhumagazin Zh.
Lecturer, Department of Solo Singing
T. Zhurgenov Kazakh National Academy of Arts
Republic of Kazakhstan, Almaty
DOI: 10.5281/zenodo.18614931

Аннотация

Статья посвящена анализу роли вокала в системе профессиональной подготовки студентов музыкальной драмы. Актуальность исследования обусловлена усложнением исполнительских требований в условиях синтетической природы музыкально-драматического искусства и необходимостью интегративного подхода к развитию профессиональных компетенций будущего исполнителя. Цель работы заключается в уточнении функционального значения вокальной подготовки, выявлении её художественно-выразительных, коммуникативных, драматургических и структурообразующих аспектов, а также определении проблемных зон и перспектив совершенствования педагогического процесса. Теоретической основой исследования выступают зарубежные и отечественные труды по вокальной педагогике, сценическому искусству и методике подготовки артистов музыкального театра. На базе анализа образовательной практики Казахской национальной академии искусств имени Т.К. Жургенова установлено, что вокал является системообразующим компонентом профессионализации, обеспечивающим формирование исполнительских компетенций и переход от технического владения голосом к сценическому действию. Выявлены методические, психофизиологические и организационно-кадровые противоречия, ограничивающие эффективность реализации вокального компонента. Обоснованы перспективы совершенствования подготовки, связанные с внедрением интегративных педагогических моделей и цифровых инструментов анализа голосового сигнала. Результаты исследования позволяют рассматривать вокальную подготовку как фактор формирования профессиональной исполнительской готовности, сценической устойчивости и профессиональной мобильности артиста музыкальной драмы.

Abstract

The article examines the role of vocal training in the professional education of musical drama students. The relevance of the study is determined by the increasing complexity of performance requirements in the context of the synthetic nature of musical drama and the need for an integrated approach to the development of professional competencies. The purpose of the research is to clarify the functional significance of vocal training, to identify its artistic-expressive, communicative, dramaturgical and structural aspects, and to outline the key challenges and prospects for the improvement of pedagogical practice. The theoretical framework of the study includes contemporary foreign and domestic research on vocal pedagogy, stage performance methodologies and the training of musical theatre artists. Analysis of the educational practice at Turar Kurmanzhanov Zhurgenov Kazakh National Academy of Arts demonstrates that vocal training serves as a system-forming component of professionalisation, ensuring the transition from technical vocal mastery to integrated stage performance. The study reveals methodological, psychophysiological and organisational contradictions that limit the effectiveness of vocal preparation within current educational models. The research identifies pedagogically relevant prospects for improvement associated with the implementation of integrative training models and the use of digital tools for vocal analysis and feedback. The findings suggest that vocal training functions as a key factor in the formation of professional performance readiness, stage resilience and artistic mobility of the future musical drama performer.

Ключевые слова: музыкальная драма; вокальная подготовка; исполнительская компетентность; сценическое исполнение; подготовка актёра; профессионализация; интегративная педагогика; синтетическое исполнительство; вокальная выразительность; драматургические функции голоса; цифровые инструменты вокального обучения.

Keywords: musical drama; vocal training; performance competence; stage performance; actor training; professionalisation; integrative pedagogy; synthetic performance; vocal expressivity; dramaturgical function of voice; digital vocal tools.

Музыкальная драма относится к синтетическим видам сценического искусства, в которых вокальное исполнение, актерское мастерство и пластика образуют единое художественное действие. В данных условиях вокальная подготовка становится одной из ключевых составляющих профессиональной подготовки исполнителя, поскольку обес-

печивает развитие сценического голоса, артикуляционно-дыхательного аппарата, музыкального слуха и выразительных средств, необходимых для создания сценического образа.

Актуальность исследования определяется повышением требований к профессиональным компетенциям артистов музыкальной драмы и необходимостью комплексного подхода к обучению. В образовательной практике отмечается тенденция перехода от раздельного освоения дисциплин (вокал, актерское мастерство, сценическая речь) к интеграции вокальных навыков в процесс формирования целостного сценического действия. Данное обстоятельство обусловливает переосмысление роли вокала не только как технической дисциплины, но и как инструмента художественной выразительности и профессиональной коммуникации актёра.

Объектом исследования является профессиональная подготовка студентов специальности «Музыкальная драма». Предмет исследования – роль вокала в формировании профессиональных компетенций будущего исполнителя. Цель исследования заключается в уточнении функционального значения вокальной подготовки в системе профессионализации студента, а также выявлении её специфики, проблемных аспектов и направлений совершенствования.

В зарубежной литературе вокальная подготовка рассматривается как ключевой компонент профессиональной подготовки исполнителей музыкального театра и музыкальной драмы. В работе Bourne T., Kenny D. показано, что систематический вокальный тренинг формирует у студентов устойчивые навыки дыхательного контроля, интонационной точности и артикуляционной ясности, что в дальнейшем определяет качество сценического звучания и музыкально-драматической выразительности [1]. Аналогичные выводы представлены у Bourne T., Garnier M. которые трактуют музыкальный театр как синтетическую форму, требующую совмещения вокала, актерского мастерства и хореографии; авторы подчёркивают, что вокал выступает звеном, обеспечивающим музыкально-смысловую структуру спектакля [2].

В эмпирических исследованиях Bourne T., Garnier M., Samson A. проведён анализ физиологических изменений голоса в процессе профессионального вокального тренинга. Авторы фиксируют повышение фонационной эффективности, улучшение резонаторного баланса и снижение выдохного расхода, что интерпретируется как признак формирования экономной вокальной техники у студентов исполнительских программ [3].

В исследованиях Oates J., Popeil L., и соавт. изучена распространённость голосовых нарушений среди студентов музыкального театра; установлено, что периоды репетиционных интенсивов коррелируют с ростом симптомов вокальной усталости и функциональной дисфонии, что требует педагогического контроля нагрузки [4]. Работа Edwards M. и коллег дополняет эти данные, указывая на необходимость включения голосовой профилактики в учебные планы, поскольку у молодых исполнителей риск голосового повреждения возникает преимущественно в процессе освоения сценических техник [5].

В педагогической литературе последних лет акцент смещается на вопросы голосовой гигиены и межстилевой вокальной подготовки. Bozeman K.W. обосновывают эффективность внедрения модулей по голосовой гигиене и фониатрической консультативной поддержки, что позволяет снижать уровень вокальной утомляемости и повышать устойчивость вокального аппарата к сценическим нагрузкам [6]. Другой ученый Horne B. описывает модель кросс-стилевой подготовки, предполагающую освоение студентами различных регистров и стилевых манер (классика, «belt», поп-рок), что соответствует изменившимся репертуарным требованиям современного музыкального театра [7].

Стилевые изменения в музыкальном театре становятся предметом анализа и в работах Rooney T.J., в котором отмечается переход от традиционного классического вокального стиля к современным смешанным техникам. Автор отмечает, что такие изменения увеличивают требования к диапазону, динамике и артикуляционной подвижности, а также требуют высокой устойчивости при совмещении вокала с физической активностью [8]. Исследования Estill J. подтверждают это, демонстрируя, что сочетание вокала с хореографическими элементами существенно изменяет параметры дыхания и фонации, что требует модификации методики обучения вокалу в сторону комплексного сценического тренинга [9].

В ряде работ поднимается вопрос о постановочной практике как факторе профессионализации. Estill J. показывает, что участие студентов в спектаклях и музыкально-драматических постановках способствует не только развитию вокальных навыков, но и формированию сценической устойчивости, ролевой идентичности и коммуникативных компетенций артиста [10]. В свою очередь Titze I. подчеркивают необходимость методической интеграции вокальной педагогики, актерского мастерства и сценического движения, рассматривая вокал не изолированно, а как элемент комплексного сценического действия [11].

В отечественной научной литературе вопросы профессиональной подготовки исполнителей музыкального театра и музыкальной драмы рассматриваются в ряде исследований казахстанских авторов. В работе Букенова Б.С. анализируется формирование артистических навыков пения в процессе профессиональной подготовки, при этом вокал определяется как значимый компонент исполнительской компетентности будущего специалиста [12]. Рахмет А.А. акцентирует внимание на методологических аспектах подготовки артистов музыкального театра, подчёркивая необходимость комплексного развития вокальных, актёрских и драматургических функций исполнения [13].

В контексте педагогических моделей подготовки специалистов в области сценического искусства Туленбаева К.М. рассматривает структуру профессиональной квалификации, где вокальный компонент обозначается в качестве важного эле-

мента междисциплинарной подготовки [14]. В исследовании Мухсиыновой М. и Каисиди И. анализируется типология вокального исполнения и его реализация в современном сценическом пространстве, что позволяет рассматривать вокал как одну из интегративных форм художественно-исполнительской практики [15]. Огородникова С.Г. фиксирует тенденции развития вокального искусства в Казахстане, указывая на институционализацию вокальной подготовки и расширение её функций в системе художественного образования [16].

Совокупность рассмотренных исследований позволяет заключить, что вокал определяется как интегративный компонент профессиональной подготовки, обеспечивающий формирование исполнительских компетенций в условиях синтетической природы музыкальной драмы.

Анализ профессиональной подготовки студентов музыкальной драмы в Казахской национальной академии искусств имени Т.К. Жургенова показывает, что вокал выполняет структурообразующую функцию в образовательной модели, поскольку обеспечивает формирование комплекса профессионально-исполнительских компетенций, соответствующих междисциплинарной природе музыкально-драматического искусства. Роль вокала в процессе профессиональной подготовки заключается в его способности выполнять одновременно художественно-выразительные, драматургические, коммуникативные и структурообразующие задания, обеспечивая перевод музыкального материала в сценическое действие. В данном контексте вокал рассматривается не как частная дисциплина, а как компонент профессиональной модели подготовки артиста музыкальной драмы.

Содержательная специфика вокальной подготовки определяется многофункциональностью сценического голоса.

На основании анализа образовательной практики и литературных источников представляется возможным выделить четыре группы функций сценического голоса:

– художественно-образная (формирование характерологических и эмоциональных признаков роли);

– коммуникативная (обеспечение межперсонажного взаимодействия и контакта со зрительным залом);

– драматургическую (участие в организации конфликта, кульминационных разворотов и динамики сценического действия);

– структурообразующая (формирование темпо-ритмических, акцентных и акустических параметров сценического пространства).

Указанные функции имеют интегративный характер и проявляются только в условиях сценического взаимодействия.

Особенностью музыкальной драмы является высокая степень синхронности исполнительских задач, включающих вокальные, актёрские, пластические и когнитивно-драматургические компоненты. Так, постановочная практика выступает ведущим механизмом профессионализации, обеспечивая трансформацию вокально-технических навыков в исполнительскую деятельность. В рамках постановочной деятельности формируются ролевые, сценические, коммуникативные и психофизиологические компетенции, содержание которых включает ролевую идентичность, сценическую устойчивость, ансамблевое взаимодействие и способность к коммуникативному сценическому поведению. Перечисленные компоненты определяют уровень профессиональной готовности исполнителя музыкальной драмы и не могут быть сформированы исключительно на основе учебно-аудиторных занятий, что подтверждает системную роль вокала в структуре подготовки.

Одновременно образовательная практика выявляет противоречия, препятствующие полноценной реализации роли вокала. Методическое противоречие заключается в несоответствии между междисциплинарной природой музыкальной драмы и дисциплинарной организацией образовательного процесса, что приводит к фрагментации подготовки. Психофизиологическое противоречие проявляется в рассогласовании между сформированными техническими навыками и их сценической реализацией, что выражается в возникновении сценической тревожности, нарушении дыхательно-резонаторной координации и снижении звучащей уверенности. Организационно-кадровое противоречие связано с дефицитом педагогов, владеющих физиолого-ориентированными вокальными техиками, адаптированными к музыкальной драме, а также отсутствием стандартизированных критериев оценки вокально-исполнительской компетентности.

Перспективы совершенствования профессиональной подготовки заключаются в переходе к интегративным педагогическим моделям, предполагающим развитие вокальных, актёрских и пластических компетенций в единой образовательной логике.

Существенные возможности открывает цифровизация вокального обучения, включая использование акустико-аналитических программ, мультимедийных модулей обратной связи и инструментов визуализации голосового сигнала, что соответствует тенденциям международной подготовки артистов музыкального театра.

В совокупности данных положений роль вокала в профессиональной подготовке студентов музыкальной драмы может быть определена как системная, обеспечивающая переход от технического владения голосом к комплексной исполнительской деятельности, включающей художественное, коммуникативное и психофизиологическое измерения.

Вокальная подготовка выполняет функцию формирования профессиональной исполнительской готовности, сценической устойчивости и профессиональной мобильности будущего артиста.

Список литературы

1. Bourne T., Kenny D. Vocal Qualities in Music Theater Voice: Perceptions of Expert Pedagogues // Journal of Voice. — 2016. — Vol. 30, № 1. — P. 128.e1-128.e12.

2. Bourne T., Garnier M. Physiological and acoustic characteristics of the female music theatre voice // The Journal of the Acoustical Society of America. — 2016. — Vol. 131, № 2. — P. 1586-1594.

3. Bourne T., Garnier M., Samson A. Physiological and acoustic characteristics of the male music theatre voice // The Journal of the Acoustical Society of America. — 2016. — Vol. 140, № 1. — P. 610-621.

4. Oates J., Popeil L., et al. Vocal tract shapes in different singing functions used in musical theater singing // Journal of Voice. — 2006. — Vol. 20, № 1. — P. 61-67.

5. Edwards M. So You Want to Sing Rock 'N' Roll: A Guide for Performers. — Lanham: Rowman & Littlefield, 2014. — 258 p.

6. Bozeman K.W. Practical Vocal Acoustics: Pedagogic Applications for Teachers and Singers. — Hillsdale: Pendragon Press, 2013. — 192 p.

7. Horne B. Voice Pedagogy for the 21st Century // Journal of Singing. — 2021. — Vol. 78, № 1. — P. 75-85.

8. Rooney T.J. The Understanding of Contemporary Vocal Pedagogy // International Journal of Learning, Teaching and Educational Research. — 2016. — Vol. 15, № 6. — P. 43-60.

9. Estill J. Estill Voice Training: Level One. Compulsory Figures for Voice Control. — Santa Rosa: Estill Voice International, 2005. — 134 p.

10. Estill J. Estill Voice Training: Level Two. Recipes for Voice Control. — Santa Rosa: Estill Voice International, 2005. — 162 p.

11. Titze I. Principles of Voice Production. 2nd printing. — Iowa City: National Center for Voice and Speech, 2000. — 245–251 p.

12. Букенов Б.С. Формирование артистических навыков пения у будущего педагога-вокалиста в процессе профессиональной подготовки // Вестник. Серия философии, культурологии и политологии. — 2019. — № 1 (67). — С. 92–98.

13. Рахмет А.А. New research and methodology in training musical theatre artists // Научная статья. — 2025.

14. Туленбаева К.М. The pedagogical system for training specialists at the Kazakh National University // ЭдЮScience. — 2025.

15. Мухсиынова М., Каисиди И. Types of vocal performance in traditional Kazakh music and their implementation in modern stage // CAJAS: Contemporary Arts Journal. — 2024. — Vol. 9, Issue 4. — С. 205–214.

16. Огородникова С.Г. Тенденции развития вокального искусства Казахстана XX–XXI веков // Искусство. — 2014.

PHILOLOGICAL SCIENCES

CROSS-LINGUISTIC SPORTS TERMINOLOGY: TYPOLOGICAL, DESCRIPTIVE, AND COMPONENTIAL ANALYSES OF AZERBAIJANI AND RUSSIAN LEXICAL SYSTEMS

Adigozalova L.
Azerbaijan Sports Academy
DOI: 10.5281/zenodo.18614935

Abstract
The goal of this article is to explore the typological features of sports terms in Azerbaijani and Russian, demonstrate their similarities and divergences, and evaluate the degree of influence from international terminological standards, primarily English. It examines definite linguistic sources, semantic classifications, structural types, mechanisms of borrowing, historical influences, and culture-specific elements shaping the terminological systems of both languages. The research contributes to the field of comparative linguistics and terminology studies, emphasizing the growing importance of international sports communication. The typological comparison shows that sports terminology in Azerbaijani and Russian is shaped by international influence, linguistic structure, and cultural history. Despite important differences in morphology and native word formation, both languages demonstrate similar strategies in borrowing and adapting modern sports vocabulary.
Keywords: sports terminology, Azerbaijani language, Russian language, comparative linguistics, typology, componential analysis, lexicography.

Sports terminology is a dynamic lexical subsystem that evolves under the influence of global sporting practices, Olympic movement, mass sports, and the professionalization of athletic disciplines. Linguistic research on sports terminology in Azerbaijani and Russian has gained relevance due to the increasing integration of both languages into international sports communication. It includes examples of comparative, descriptive, and typological linguistic methods. Sports terminology represents a dynamic subsystem of the lexical structure of national languages and reflects both linguistic processes and sociocultural development. The formation of modern sports terminology in the Azerbaijani and Russian languages is shaped by institutional documents, national federations, and international organizations such as the IOC and specialized sports bodies.

In the Azerbaijani context, terminological development has been systematically studied, particularly in relation to the evolution of modern terminology and codification practices[1].

For Russian sports terminology, one of the most authoritative sources remains the explanatory dictionary by Bleer, Suslov, and Tyshler, which provides standardized definitions and semantics of professional sports terms.

The descriptive method was employed to systematically observe and record the features of sports terminology in both languages. For example, in analyzing the Azerbaijani term *güləşçi* (wrestler), the method involved breaking down the word into its root *güləş* and agentive suffix *-çi* to describe its morphological structure and semantic function. Similarly, the Russian term *борец* was analyzed as root *бор-* plus suffix *-ец*. The descriptive method allows precise identification of morphemes, word formation patterns, and meaning relationships.

The comparative-typological method was applied to identify parallels and differences in sports terminology between Azerbaijani and Russian. Examples include:

Concept	Azerbaijani Term	Russian Term	Observations
Wrestler	*güləşçi*	*борец*	Both use derivational suffixes to form agent nouns; Azerbaijani uses agglutinative *-çi*, Russian fusional *-ец*
Runner	*qaçışçı*	*бегун*	Parallel agentive constructions; morphological structures differ due to language type
Freestyle wrestling	*sərbəst güləş*	*вольная борьба*	Both are compound terms; Azerbaijani nominal cluster, Russian adjective+noun
Speed training	*sürət məşqi*	*скоростная тренировка*	Multiword technical term; attribute position differs (post-nominal in AZ, pre-nominal in RU)
Ball Control	*topa nəzarət*	*контроль мяча*	Phrase structure illustrates syntactic variation while maintaining semantic equivalence

[1] Həsənov, R. *Azərbaycan dilində terminologiyanın inkişafı*, Bakı, 2020

The componential analysis method was used to break down complex sports terms into their semantic features (components) to reveal shared and distinctive elements. The same examples can be presented using the comparative analysis method.

Term	Semantic Components	Language
güləşçi (wrestler)	[+human], [+athlete], [+wrestler]	Azerbaijani
борец (wrestler)	[+human], [+athlete], [+wrestler]	Russian
sürət məşqi (speed training)	[+training], [+speed], [+physical]	Azerbaijani
скоростная тренировка (speed training)	[+training], [+speed], [+physical]	Russian
hücumçu (forward)	[+human], [+athlete], [+offense], [+team role]	Azerbaijani
нападающий (forward)	[+human], [+athlete], [+offense], [+team role]	Russian

This method highlights the core semantic features, showing how similar roles and actions are represented across both languages while allowing for nuanced differences in lexical expression.

The typological comparison shows that sports terminology in Azerbaijani and Russian is shaped by international influence, linguistic structure, and cultural history. Despite important differences in morphology and native word formation, both languages demonstrate similar strategies in borrowing and adapting modern sports vocabulary.

Typological analysis also involves comparing dictionaries across languages based on their structure, content, purpose, and lexicographic principles. In the context of sports terminology, Russian and Azerbaijani lexicography show both shared traditions and language-specific characteristics. The typological comparison shows that Russian sports lexicography is more developed in terms of standardization, dictionary volume, and explanatory depth. Azerbaijani sports dictionaries, influenced by Russian and global English terminology, are still growing and tend to be translation-oriented. Both languages share many international sports terms, but structural, morphological, and semantic representation differs substantially.

Talking about general lexicographic background, we can say that Azerbaijani sports terminology has developed mainly during the 20th–21st centuries alongside modernization of national sports and international integration (AFFA, PFL, National Olympic Committee documents). Many terms originated from Russian and English, especially during the Soviet period and after independence. Dictionaries tend to be translation-oriented, focusing on practical use.

Russian sports lexicography is older and more extensive, with dictionaries from Soviet times and modern corpora. Terminology is relatively standardized due to strong sports federations and scientific literature. Russian dictionaries are often explanatory and encyclopedic.

Typological Features that are common for both Languages are

Both languages exhibit substantial influence from English-based global terminology.

Azerbaijani maintains clearer morphological transparency due to its agglutinative nature.

Russian supports deeper historical layers from French, German, and Slavic sources.

Here are some examples from Russian Sports Terminological Dictionaries / Corpora

1. From *Терминология спорта: толковый словарь-справочник* by A. N. Bleer, F. P. Suslov, D. A. Tyshler [2]

e.g. Снаряды спортивные — "a number of special industrial items intended for the performance of particular exercises and having characteristics regulated by competition rules; for example: athletics (discus, shot put, pole), weightlifting (barbell, kettlebells, dumbbells)".

e.g. Спартакиада — "a complex multi-sport competition that includes several sports, historically held in the Soviet Union, such as Spartakiads of republics, workers, schools, etc."

e.g. Гандикап — although not originally Russian, used in Russian sports lexicon to mean the "system allowing weaker participants to have an advantage, e.g., in multi-stage competitions."

2. **From linguistic / corpus-based analysis (ice hockey terminology)**

In the paper *Structural and semantic features of sports terms (on the example of ice hockey)*, authors analyze terms like **»шайба» ("puck")** and **»клюшка" ("stick")**.

Шайба: its meaning in ice hockey goes beyond just "puck" — in contexts, semantic components include [+object], [+flat], [+used in gameplay], and metaphorical or metonymic meanings (because in match commentary, size, shape, weight are often evoked).

Клюшка: similarly, it denotes "hockey stick" but the analysis shows its multi-layered semantics in corpora, especially descriptive speech of commentators.

3. **From linguistic research on borrowings in Russian sports terminology**

In the article *Borrowings in Russian Sports Terminology* (Musina G., Satarova L) the authors use the "Dictionary of Sports Terms" by R. R. Salimzyanov as a key source. [3]

They list two-component and three-component borrowed or compound sports terms, for example:

[2] Bleer, A. N., Suslov, F. P., Tyshler, D. A. *Terminologiya sporta: tolkovyy slovar-spravochnik*. (Sports Terminology: An Explanatory Dictionary and Reference Guide) Moscow, 2010.

[3] Borrowings in Russian sports terminology Musina G. F. Satarova L, 2023

полуфинал (semifinal), *хет-трик* (hat-trick), *интенсивность тренировки* (training intensity), *теория физической культуры* (theory of physical culture).

Here are some comparing examples from Official Documents (AFFA, PFL, and other Azerbaijani Sports Federations)

1. **AFFA (Association of the Football Federations of Azerbaijan) – Registration / Player Passport ("BURAXILIŞ 2025")[4]**

In the AFFA document *BURAXILIŞ 2025: Qeydiyyat qaydaları və futbolçu pasportunun tərtibi* (Release 2025 – Registration & Player Passport Rules), the term **"futbolçu pasportu"** ("player passport") is used.

Typological note: This is a compound term in Azerbaijani: **futbolçu and pasportu** ("player and his/its passport").

Terminological significance: It refers to a formal identity document specifically for footballers, not a general personal passport — showing institutional terminology in registration systems.

2. **AFFA – Licensing for Coaches / Clubs**

In the issue of 2025, there is mention of **"müvafiq məşqçilik lisenziyası"** ("relevant coaching license").

Typological note: This is a phrase (multiword term) — *məşqçilik ("coaching") + lisenziyası ("license")*.

Terminological significance: This is a key regulatory term used in the federation's licensing system, and indicates how "license / lisenziya" is borrowed but adapted into Azerbaijani governance language.

3. **AFFA – Age-Group League Regulatory Term**

In the **AFFA U-11 League Statutes ("Əsasnamə")** document, the terms **"ışıtirakçı komanda", "liqa"**, and **"Fair-Play prinsipləri"** appear.

"İştirakçı komanda" = "participating team" — a technical phrase in the rules.

"Liqa" = "league" — used in Azerbaijani though borrowed from foreign sports vocabulary.

"Fair-Play prinsipləri" = "fair play principles" — a direct borrowing of the English "fair play".[5]

4. **AFFA – U-14 Girls League Statutes**

In the **AFFA U-14 Girls League Regulations (Əsasnamə)**, the phrase **"komanda forması"** (team uniform), **"texniki zona"** (technical zone), and **"yüksək rəqəm"** ("number on the back") are used.

Typological note: These are multiword regulatory terms.

Terminological significance: They reflect the formal language used by national federation to regulate match, uniforms, and match protocol.

5. **Azərbaycan Tennis Federasiyası (Azerbaijan Tennis Federation)**

In the *"Tennis idman növü üzrə idmançılara lisenziyaların verilməsi qaydası"* (Azerbaijan Tennis Federation's Rules on Granting Licenses to Athletes), the document defines **"konversiya prosesi"**, **"sezon"**, **"idman klubu"**, and **"sağlamlıq kağızı"**.

"Konversiya prosesi" ("conversion process") — the change of license type, institutional term.

"Sezon" ("season") — borrowed but institutionalized.[6]

"Idman klubu" ("sport club") — standard institution term.

"Sağlamlıq kağızı" ("health certificate / document") — formal term used in licensing.

Here are examples from Russian Federations / National Olympic Committee documents

1. **Use of "Олимпийский" in Official Names (ROC)**

According to the Russian Olympic Committee's document *"Об использовании слова 'олимпийский'"* ("On the use of the word 'Olympic'") the ROC regulates how organizations can use "олимпийский - olympic", "паралимпийский- paralympic", and "сурдлимпийский- deaflympic" in their titles. [7]

Here we can say that according to the Terminological notes:

"Олимпийский комитет России" ("Olympic Committee of Russia") – institutional name, shows a formalized term, **"слово «олимпийский – word Olympic» … или образованные на его основе словосочетания – and based on it a word combination"** – demonstrates a terminological rule about word formation (root + derived phrases).

This is a governance term, not a sports technique, but very important for the terminological system because it defines how "Olympic / Paralympic" are used in organizational contexts.

2. **Resolution of the Ministry of Sport on Use of "Олимпийский" / "Паралимпийский" / "Сурдлимпийский"**

Приказ Министра спорта РФ № 912 от 11.12.2020 (the Resolution of the Ministry of Sport of Russian Federation No 912 from 11.12.2020) establishes the **procedure for sports organizations** (which run educational sports programs) to use in their name: "олимпийский- Olympic", "паралимпийский-paralympic" or "сурдлимпийский- deaflympic" or derivatives thereof.

Terminological significance: This legal / regulatory document standardizes the use of these highly loaded institutional terms — it is a terminological regulation rather than purely technical sport vocabulary.

3. **Federal Law on Sport (329-ФЗ)**

In **Federal Law No. 329-ФЗ "On Physical Culture and Sport"**, there is a clear terminological definition of *"спорт / спортивная деятельность – sport/sports activities"*, *"вид спорта- kind of sport"*, and also for *"паралимпийское движение – Paralympic movement / специальная олимпиада России- special Olympic of Russia / Сурдлимпийский комитет – deaflympic committee*", etc.

Examples from the law:

[4] 3. AFFA (Association of Football Federations of Azerbaijan). *Qeydiyyat qaydaları və futbolçu pasportu*.

[5] 4. AFFA. *U-11 Liqa Əsasnaməsi*. Official publications

[6] Azerbaijan Tennis Federation. *Tennis idman növü üzrə idmançılara lisenziyaların verilməsi qaydası*.

[7] Russian Olympic Committee. *Ob ispol'zovanii slova «olimpiyskiy»*. olympic.ru.

«вид спорта – kind of sport» — a legally defined concept ("sport type / discipline") in the context of national registration and regulatory classification.

"паралимпийское движение России – Paralympic movement of Russia", *"сурдлимпийское движение России- dealympic movement of Russia"* — formal institutional terminology embedded in legal state-level sport definitions.

4. **Documents of the Sports Federation — Russian Federation of Alpine Skiing (RFGS)**

On the **RFGS (Российская федерация горнолыжного спорта-Russian Alpine Skiing Federation)** website under "Документы - documents", they publish *Правила вида спорта – Rules of the kind of sport "горнолыжный спорт"* (alpine skiing) approved by the Ministry of Sport.

Terminological examples:

"вид спорта" — "type of sport" (this term is both legal and technical in the rules).

"Квалификационные критерии" ("Qualification criteria") may appear in these rules, referring to athlete eligibility, ranking, competition structure.[8]

5. **Regulations of Equestrian Sport (FEI, via Russian Federation)**

In the *Общий регламент, 24-е издание* (General Regulations, 24th edition) on the Russian equestrian federation site, it states that athletes, teams, or staff must be **"заявлены своим Национальным Олимпийским Комитетом"** ("declared by their National Olympic Committee").[9]

Terminological points:

Use of *"Национальный Олимпийский Комитет"* ("National Olympic Committee") — formal institutional term.

"Официальное лицо команды" ("an official team person") — technical-regulatory phrase.

"критерии допуска" ("admission / qualification criteria") — rule-based term used in the regulatory system.

Globalization accelerates term borrowing and linguistic convergence. Similarities could be revealed in

- Alphabetical dictionaries (e.g., *Idman terminlərinin lüğəti- Dictionary of Sports Terms*, *Словарь спортивных терминов*).
- Thematic/discipline-based dictionaries (football, athletics, wrestling).
- Multilingual dictionaries (AZ–RU–EN; RU–EN–DE, etc.).

Typological differences between Russian and Azerbaijani sports dictionaries are the following:

Features of structural differences	**Azerbaijani sports dictionaries**	**Russian sports dictionaries**
Type	Mostly bilingual (AZ–RU, AZ–EN)	Often monolingual (RU) or multilingual
Definiton Style	Short, practical, translation-focused	Detailed, scientific, sometimes encyclopedic
Examples	Not always provided	Frequently included
Borrowed terms often assimilate phonologically and morphologically (*пенальти*, *дриблинг*).	Lower variability of terms	Higher standardized terms through federations

Semantically Russian dictionaries tend to include:

- broader semantic explanations,
- phraseology (e.g., *вне игры*, *домашний матч*, *игра в один касание*),
- stylistic labels (professional, colloquial).

and Azerbaijani dictionaries:

- focus on equivalents rather than semantic nuances,
- phraseology is less represented,
- fewer stylistic notes.

Observing typological patterns taken from dictionaries it can be said that Azerbaijani Dictionaries are mostly translation-based and concise. They provide only essential functional definitions. There are often lack classification, variants, examples, or stylistic labels in the dictionaries. Less standardized terminology across sources can be revealed.

Russian Dictionaries are detailed, explanatory, often encyclopedic. They provide rule-based, scientific, or technical classifications, include stylistic labels, examples, subentries. Dictionaries are highly standardized due to federation and Soviet lexicographic tradition.

References

1. Həsənov, R. *Azərbaycan dilində terminologiyanın inkişafı*. Bakı., 2020

2. Bleer, A. N., Suslov, F. P., Tyshler, D. A. *Terminologiya sporta: tolkovyy slovar-spravochnik*. (Sports Terminology: An Explanatory Dictionary and Reference Guide) Moscow, 2010.

3. Borrowings in Russian sports terminology Musina G. F. Satarova L, 2023

4. AFFA (Association of Football Federations of Azerbaijan). *Qeydiyyat qaydaları və futbolçu pasportu*.

5. AFFA. *U-11 Liqa Əsasnaməsi*. Official publications

[8] RFGS (Russian Federation of Alpine Skiing). *Pravila vida sporta «gornolyzhnyy sport»*

[9] FEI (International Federation for Equestrian Sports). *General Regulations*.

6. Azerbaijan Tennis Federation. *Tennis idman növü üzrə idmançılara lisenziyaların verilməsi qaydası*.

7. Russian Olympic Committee. *Ob ispol'zovanii slova «olimpiyskiy»*. olympic.ru.

8. RFGS (Russian Federation of Alpine Skiing). *Pravila vida sporta «gornolyzhnyy sport»*

9. FEI (International Federation for Equestrian Sports). General Regulations.

TECHNICAL SCIENCES

СОВРЕМЕННЫЕ ИННОВАЦИИ В УСТОЙЧИВОЙ ОБРАБОТКЕ ФРУКТОВ И ОВОЩЕЙ. ОБЗОР

Бурак Л.Ч.
https://orcid.org/0000-0002-6613-439X
доктор философии в области пищевых наук (PhD), к.т. н,
директор ООО «БЕЛРОСАКВА», Республика Беларусь, г. Минск.
Саманкова Н.В.
https://orcid.org/0000-0003-4518-3480
Белорусский государственный экономический университет,
доцент кафедры товароведения и экспертизы товаров, к.т.н. Минск, Беларусь

CONTEMPORARY INNOVATION IN SUSTAINABLE FRUIT AND VEGETABLE PROCESSING: REVIEW

Burak L.
https://orcid.org/0000-0002-6613-439X
Doctor of Philosophy in Food Sciences (PhD), c. t. s.,
director of BELROSAKVA LLC, Republic of Belarus, Minsk
Samankova N.
https://orcid.org/0000-0003-4518-3480
Belarusian State University of Economics, Associate Professor of the Department of Commodity Science and Expertise of Goods, PhD in Engineering Minsk, Belarus
DOI: 10.5281/zenodo.18614946

Аннотация

Пищевая промышленность находится на пороге значительных изменений, направленных на достижение устойчивого развития. Высокие уровни потерь после сбора урожая, достигающие 40% для фруктов и овощей, требуют внедрения эффективных решений для снижения воздействия на окружающую среду. Цель данного исследования — проанализировать новейшие инновации в области устойчивой послеуборочной обработки, направленные на улучшение качества продукции, продление срока хранения и уменьшение отходов. Проведен научный поиск в научных базах данных и анализ публикаций за период 2020-2026 годы. Исследование охватывает достижения в области нетермической и минимальной обработки, а также экологически чистых упаковочных решений. Инновационные технологии, такие как ультразвук, импульсные электрические поля и съедобные покрытия, показали свою эффективность в сохранении питательных веществ и безопасности продуктов, одновременно снижая потребление энергии. Несмотря на потенциал интегрированных технологий, которые могут уменьшить порчу на более чем на 70 процентов, остаются значительные вызовы, включая глобальные потери и высокие затраты на внедрение наноструктурированных материалов. Использование биоразлагаемых упаковок и интеллектуальных систем для мониторинга свежести также представляет собой важный шаг к устойчивости. Внедрение этих интегрированных стратегий, включая циклическую биоэкономику для повышения ценности побочных продуктов, открывает новые горизонты в борьбе с послеуборочными потерями, способствует продовольственной безопасности и формирует экологически устойчивую систему производства свежих продуктов.

Abstract

The food industry is facing significant changes aimed at achieving sustainable development. High levels of postharvest losses, reaching 40% for fruits and vegetables, require the implementation of effective solutions to reduce environmental impact. The objective of this study is to analyze the latest innovations in sustainable post-harvest processing aimed at improving product quality, extending shelf life, and reducing waste. A scientific search of scientific databases and an analysis of publications for the period 2020-2026 were conducted. The study covers advances in non-thermal and minimal processing, as well as environmentally friendly packaging solutions. Innovative technologies such as ultrasound, pulsed electric fields, and edible coatings have proven effective in preserving nutrients and food safety while reducing energy consumption. Despite the potential of integrated technologies that can reduce spoilage by more than 70 percent, significant challenges remain, including global losses and the high costs of implementing nanostructured materials. The use of biodegradable packaging and intelligent freshness monitoring systems also represents a significant step toward sustainability. The implementation of these integrated strategies, including a circular bioeconomy to enhance the value of by-products, opens new horizons in combating post-harvest losses, promotes food security, and creates a sustainable fresh food production system.

Ключевые слова: устойчивое развитие, послеуборочная обработка, инновации, биоразлагаемая упаковка, хранение, ультразвук, съедобные покрытия.

Keywords: sustainability, post-harvest processing, innovation, biodegradable packaging, storage, ultrasound, edible coatings.

ВВЕДЕНИЕ

Послеуборочные потери плодоовощной продукции остаются одним из ключевых ограничителей глобальной продовольственной безопасности и экологической устойчивости. Высокая скоропортимость фруктов и овощей делает их особенно чувствительными к нарушениям технологий обращения: травмирование при сборе и сортировке, недостаточная санитария, задержки при транспортировке и несоблюдение режимов хранения закономерно приводят к потере массы, ухудшению качества и микробиологической порче. По оценкам, суммарные мировые потери на послеуборочных этапах для данной группы продукции составляют порядка 20–40% и варьируют в зависимости от региона, инфраструктуры и организации цепочки поставок [1].Масштаб проблемы сопоставим с утратой значительной доли продовольствия, предназначенного для питания человека, что усиливает экономические риски для производителей и торговых сетей и одновременно повышает «ресурсоёмкость» конечного продукта (вода, энергия, земельные ресурсы) [2]. Наиболее уязвимыми остаются страны с низким и средним уровнем дохода: дефицит мощностей предварительного охлаждения, складской инфраструктуры и надежной холодовой цепи часто обуславливает потери свыше 30% [3, 4]. Следовательно, снижение послеуборочных потерь следует рассматривать не как локальную технологическую задачу, а как системную меру повышения эффективности агропродовольственных цепочек. В логике устойчивого развития цепочка создания стоимости может считаться устойчивой тогда, когда наряду с социально-экономическими эффектами обеспечивается сохранение природного капитала для будущих поколений [5]. Поэтому сокращение потерь и пищевых отходов напрямую соотносится с повесткой Целей устойчивого развития, включая задачи рационального потребления и производства, технологической модернизации инфраструктуры и климатической ответственности [6, 7]. Актуальность усиливается прогнозируемым ростом спроса на продовольствие к 2050 г., что делает внедрение результативных послеуборочных стратегий необходимым условием поддержания продовольственной обеспеченности [5, 6].Для достижения заметного эффекта требуются многоуровневые решения: совершенствование практик послеуборочной обработки и подготовки кадров, инвестиции в инфраструктуру хранения и транспортировки, развитие прикладных исследований и механизмов внедрения. Глобальные аналитические документы подчеркивают, что недостаточная адаптация к изменению климата и смягчение его последствий относятся к числу наиболее значимых мировых рисков, что дополнительно повышает ценность технологий ресурсосбережения и сокращения потерь [7, 8]. В этой связи «зелёные» инновации — от модернизации процессов до экологизации продуктов и услуг — рассматриваются как инструмент снижения негативного воздействия на окружающую среду за счет более чистых технологий и экономии сырья [9]. Практическая значимость подтверждается тем, что существенная доля потерь свежей продукции по-прежнему связана именно с недостатками послеуборочной обработки, хранения и логистики [10]. Цель данного исследования — проанализировать новейшие инновации в области устойчивой послеуборочной обработки, направленные на улучшение качества продукции, продление срока хранения и уменьшение отходов

МАТЕРИАЛЫ И МЕТОДЫ

Обзор выполнен по научным источникам, опубликованным в период 2020–2026гг. Поиск литературы на русском и английском языках проводили в библиографических базах Web of Science, Scopus и Google Scholar. Для поиска применяли набор дескрипторов, отражающих тематику исследования: послеуборочная обработка плодов и овощей, снижение послеуборочных потерь, технологии хранения, холодовая цепь, модифицированная атмосфера, не-тепловые методы обеззараживания и обработки (холодная плазма, УФ-облучение, импульсный свет, ультразвук, высокое гидростатическое давление, импульсные электрические поля), съедобные покрытия, активная и «интеллектуальная» упаковка, экологически безопасные упаковочные материалы, нанотехнологии и устойчивые решения в цепочке поставок. Первичный поиск позволил отобрать и проанализировать 987 публикаций. Далее применяли этапы аналитического отбора: удаление дубликатов, оценка релевантности по названию и аннотации, последующий полнотекстовый анализ. В итоговый массив включали работы, удовлетворяющие критериям: соответствие объекту исследования (послеуборочные технологии для свежей и минимально обработанной плодоовощной продукции), принадлежность к периоду 2020–2026гг., наличие описания методики и результатов, достаточных для интерпретации и сопоставления. Исключали публикации, не относящиеся к плодоовощной продукции, не содержащие экспериментальных данных/обобщающих выводов по послеуборочной обработке, а также материалы с неполными библиографическими сведениями. По итогам отбора для подготовки обзора было включено 79 исследований.

РЕЗУЛЬТАТЫ И ИХ ОБСУЖДЕНИЕ

1. Устойчивые технологии послеуборочной обработки: вызовы, возможности и критические пробелы

Послеуборочная порча плодоовощной продукции формируется комплексом физиологических и биохимических изменений, микробиологической контаминации, а также факторов хранения и логистики. При этом традиционные меры снижения потерь часто опираются на энергоёмкие операции, синтетические реагенты и упаковку из невозобновляемого сырья, что создаёт компромиссы между безопасностью продукта, затратами и экологическими последствиями. Поэтому устойчивые решения в области послеуборочной обработки должны одновременно обеспечивать санитарную надёжность, снижать негативное воздействие на окружающую среду, сохранять экономическую целесообразность и соответствовать ужесточающимся нормативным требованиям. Фрукты и овощи остаются

метаболически активными после уборки урожая: дыхание, созревание и старение продолжаются, ускоряя снижение качества. Высокая влажность и наличие доступных субстратов создают условия для быстрого роста микрофлоры, что усиливает порчу [2, 4, 5]. Существенная доля послеуборочных потерь связана с физиологическим ухудшением, которое усугубляется технологическими, биологическими и экологическими факторами (температурные нарушения, механические повреждения, задержки на этапах охлаждения и транспортирования) [11]. В связи с исходно коротким сроком хранения плодоовощной продукции эффективные вмешательства должны быть своевременными и точно подобранными под конкретный объект [4]. Недостатки послеуборочного обращения приводят к экономическим потерям на всех этапах цепочки поставок и негативно отражаются на доходах производителей и продовольственной доступности [4]. Дополнительно ухудшается пищевая ценность: при порче и неправильном хранении снижается содержание отдельных микронутриентов, включая витамины А и С, что особенно критично для свежей продукции [6]. На системном уровне неэффективность послеуборочных операций связана с существенными финансовыми потерями и заметным вкладом в углеродный след продовольственной системы [10]. Параллельно меняются потребительские установки: возрастает внимание к экологическим последствиям упаковки и усиливается запрос на замещение нефтехимических полимеров более устойчивыми материалами [13–15]. Одновременно развивается спрос на минимально обработанные продукты без консервантов («чистая этикетка»), что стимулирует внедрение физических и биологических альтернатив традиционной химической санации [1, 16–18]. В этих условиях нетермические технологии рассматриваются как ключевой класс устойчивых инструментов послеуборочной обработки. Они позволяют повышать микробиологическую безопасность и стабилизировать качество при меньшем тепловом воздействии, снижении энергозатрат и потенциальном уменьшении потребности в химических дезинфектантах [2, 19–22]. Однако их промышленное применение часто ограничивают высокая стоимость оборудования, поверхностный характер воздействия у ряда методов, трудности стандартизации и масштабирования, а также риск нежелательных изменений качества при некорректной оптимизации режимов. Поэтому в практике и научных работах всё чаще обсуждаются комбинированные (гибридные) схемы, где эффект достигается за счёт согласования мягких режимов нескольких воздействий. Сравнительные характеристики наиболее распространённых нетермических, экологически ориентированных технологий представлены в таблице 1.

Таблица 1.

Нетермические экологически ориентированные технологии послеуборочной обработки

Наименование технологии	Принцип действия и область применения	Ожидаемая эффективность	Ограничения и проблемы	Источник
Высокое гидростатическое давление (ВГД) / обработка высоким давлением	Нетермическое воздействие давлением для инактивации микроорганизмов и снижения активности ферментов; применяется для минимально обработанных плодов и овощей и отдельных видов цельной продукции; в ряде случаев способствует сохранению/изменению профиля биоактивных соединений	Снижение микробной нагрузки; уменьшение ферментативного потемнения; сохранение цвета/текстуры при оптимальных режимах; возможное повышение/сохранение нутрицевтических компонентов	Высокая стоимость оборудования; ограничения для пористых/газосодержащих матриц; риск изменений текстуры; чаще периодический режим (batch), что усложняет масштабирование и производительность	[2, 5, 14, 23–25]
Импульсные электрические поля (ИЭП, PEF)	Короткие импульсы высокоинтенсивного электрического поля при минимальном нагреве; применяются для повышения безопасности и управляемого воздействия на свойства продукта; более подходят для однородных и перекачиваемых сред	Повышение микробиологической безопасности при низком тепловом воздействии; снижение активности ряда ферментов; уменьшение потемнения; улучшение технологических свойств при корректной оптимизации	Высокие капитальные вложения; ограниченная применимость для неоднородных/неперекачиваемых матриц; возможная коррозия электродов; сложная настройка режимов	[30–35]

Холодная плазма	Генерация активных форм кислорода и азота при ионизации газа; преимущественно поверхностная дезинфекция сырья, упаковки и контактных поверхностей; рассматривается как альтернатива химическим санитизаторам	Снижение поверхностной контаминации; замедление микробной порчи; потенциальное продление срока хранения при сохранении «свежеподобного» качества	Воздействие в основном на поверхность; риск окислительных изменений чувствительных компонентов; недостаток стандартизации оборудования; регуляторные различия	[36–41]
Ультрафиолетовое излучение С (УФ-С)	Инактивация микроорганизмов через повреждение ДНК; может индуцировать защитные реакции тканей и влиять на отдельные процессы созревания; применяется для обработки поверхности плодов/овощей и тары	Снижение микробной обсеменённости поверхности; уменьшение/замедление развития гнилей; возможная задержка созревания; индукция защитных метаболитов при мягких дозах	«Теневой эффект» на неровной поверхности; риск стресс-повреждений при передозировке; требования к защите персонала; трудности равномерного дозирования	[42–47]
Импульсный свет (PL)	Серии коротких импульсов интенсивного широкоспектрального света; инактивация микроорганизмов фотохимическими и фототермическими эффектами; подходит для поверхностной обработки	Быстрая инактивация поверхностной микрофлоры; снижение риска перекрёстной контаминации; потенциальное продление срока хранения без химической нагрузки	Низкая проникающая способность; возможный локальный нагрев и изменения поверхности/окраски; требования безопасности; стоимость оборудования	[48–50]
Озон + модифицированная газовая среда (MAP)	Комбинация газовой модификации и озонирования для подавления микрофлоры и замедления порчи (часто для ягод); реализуется в упаковочных/предупаковочных схемах	Снижение микробной нагрузки; замедление порчи; увеличение срока хранения; уменьшение частоты гнилей при корректном управлении газовой средой	Необходим контроль остаточного озона (риск посторонних привкусов/повреждения тканей); различия в нормативных ограничениях; риск окислительного стресса у чувствительных культур	[4, 51–55]
Ультразвук	Кавитационные эффекты и микроструи могут снижать микробную обсеменённость и активность ферментов; используется самостоятельно или в сочетаниях (например, с водными средами/мягкими реагентами)	Снижение микробной нагрузки на поверхности и в моечных средах; частичная инактивация ферментов; улучшение санитарной обработки; потенциальное продление срока хранения при оптимальных режимах	При высокой интенсивности — риск размягчения тканей и клеточного повреждения; ограниченная глубина; энергоэффективность зависит от среды и конструкции оборудования	[56–66]

Примечание. Выраженность эффектов (например, снижение микробной нагрузки, замедление потемнения, сохранение витамина С, изменение твёрдости/массы, увеличение срока хранения) существенно зависит от вида и сорта продукции, степени зрелости, исходной обсеменённости, дозы/интенсивности и времени воздействия, температуры, а также условий последующего хранения и упаковки. Поэтому при сопоставлении результатов разных исследований корректно учитывать протокол обработки и параметры хранения.

2. Инновации в области экологически чистой упаковки и проблемы регулирования

Для корректной интерпретации текущих трендов упаковочные решения целесообразно рассматривать не изолированно, а в связке с ограничениями внедрения: масштабируемостью, совокупной стоимостью владения, совместимостью с действующими линиями, а также регуляторными требованиями и ожиданиями потребителей. В литературе 2020–2026гг. экологизация упаковки для свежей плодоовощной продукции описывается как переход от «пассивной защиты» к функциональным системам, которые одновременно снижают экологический след и поддерживают качество/безопасность продукта на протяжении хранения и дистрибуции. Упаковка остаётся критически важным барьером для скоропортящихся продуктов, поскольку снижает механические повреждения, ограничивает обезвоживание и замедляет нежелательные изменения качества. Однако традиционные нефтехимические полимеры усиливают нагрузку на окружающую среду, что стимулирует развитие биоразлагаемых и компостируемых материалов, а также съедобных форматов упаковки. Параллельно усиливается интерес к активной и интеллектуальной упаковке, способной воздействовать на микросреду продукта и обеспечивать мониторинг свежести, тем самым повышая управляемость качества и пищевой безопасности.

2.1. Съедобные покрытия как «минимальная» упаковка

Съедобные покрытия рассматриваются как устойчивый вариант, формирующий тонкую плёнку из натуральных биоразлагаемых полимеров: полисахаридов (например, хитозан, крахмал), белков (сывороточный белок, зеин) и липидов (воски) [10]. Функционально такие покрытия выступают полупроницаемыми барьерами: регулируют газообмен, уменьшают потерю влаги и могут подавлять рост микроорганизмов, что способствует продлению срока хранения без выраженного остаточного вкуса или запаха. Наиболее распространённый исследовательский вектор — покрытия на основе хитозана, дополненные эфирными маслами и природными антиоксидантами/экстрактами (в т.ч. алоэ вера) для усиления антимикробного и антиоксидантного эффекта [17]. К ключевым ограничениям относят вариабельность стоимости сырья и рецептур, сложности промышленного равномерного нанесения, а также факторы потребительского восприятия (видимость слоя, изменения текстуры, ощущение «дополнительной плёнки»). Для производителей это означает необходимость адаптации технологических линий и усиления контроля качества, чтобы обеспечить стабильность покрытия и воспроизводимость эффекта.

2.2. Биополимеры, биокомпозиты и функциональная упаковка

Переход к экологически ориентированным материалам обусловлен экологическими издержками нефтехимических полимеров (истощение ресурсов, загрязнение) [14]. В качестве альтернативы рассматриваются биопластики из возобновляемой биомассы (кукурузный крахмал, сахарный тростник, водоросли) — в том числе полимолочная кислота (PLA) и крахмалсодержащие плёнки, способные к биоразложению/компостированию и потенциально лучше вписывающиеся в логику циклической экономики [67]. Отдельное направление — активные и интеллектуальные решения. Активная упаковка продлевает срок хранения через введение антиоксидантов и антимикробных компонентов, включая соединения из экстрактов сельскохозяйственных отходов, которые высвобождаются в микросреду продукта контролируемо [68]. Интеллектуальная упаковка усиливает коммуникационную функцию: индикаторы и сенсоры (например, pH-чувствительные красители или биосенсоры) предоставляют информацию о состоянии продукта (свежесть, температурные нарушения, признаки порчи) в режиме, близком к реальному времени [69].

С инженерной точки зрения устойчивые конструкции упаковки также включают «логистические» инновации: облегчённые и многоразовые решения, штабелируемые контейнеры и складные ящики, которые повышают эффективность перевозки и снижают риск повреждения продукции [70].

2.3. Регуляторные барьеры и рыночное принятие

Критическим сдерживающим фактором остаётся фрагментация требований к материалам, контактирующим с пищей: различия между юрисдикциями повышают неопределённость, удлиняют вывод продукта на рынок и увеличивают затраты на подтверждение соответствия. Отдельно осложняют коммерциализацию вопросы миграции компонентов и токсикологической оценки, включая случаи применения (био)наноматериалов. На стороне спроса барьером остаётся неоднозначность потребительского понимания «экологичности», особенно на развивающихся рынках: устойчивость чаще связывают с биоразлагаемостью и перерабатываемостью, тогда как цена и внешний вид упаковки продолжают существенно влиять на выбор [13]. Дополнительный импульс переходу к альтернативам традиционному пластику придают политические меры по ограничению одноразовых изделий (в ЕС — с 2021 г.) [71]. В совокупности это формирует ключевой практический конфликт: упаковка должна быть одновременно экологичной, технологичной (прочность, барьерные свойства), безопасной в контакте с пищей и экономически конкурентоспособной. Поэтому в исследованиях 2020–2026гг. особое внимание уделяется биокомпозитам на основе вторичных биоресурсов (кофейная гуща, агропобочные продукты, лигноцеллюлозная биомасса), которые потенциально снижают стоимость сырья и улучшают свойства материалов [72]. При этом для лигноцеллюлозных наполнителей типичны проблемы влагопоглощения и совместимости с матрицей; для их решения предлагаются подходы модификации и компатибилизации, включая варианты «зелёной» обработки органоглин и функциональных добавок [71].

Сравнительные характеристики наиболее часто обсуждаемых биоразлагаемых материалов

Таблица 2.

Ключевые биоразлагаемые материалы для пищевой упаковки: свойства и ограничения

Материал	Источник материала	Эффективность	Ограничения	Ссылки
PLA	Ферментация сахаров (растительное сырьё)	Хорошие механические и газобарьерные свойства, прозрачность, технологичность	Хрупкость, стоимость; часто требует смесей/наполнителей	[14, 67]
Крахмал	Кукуруза/маниока/картофель	Дешёвый, доступный; улучшает биоразложение смесей; пригоден для съедобных плёнок	Гидрофильность → слабый влагобарьер	[14, 16, 67, 73]
Хитозан	Отходы ракообразных/рыбы	Антимикробность, хорошие плёнки, газовый барьер	Слабая влагостойкость; чувствительность к рецептуре	[14, 16]
Пектин	Цитрусовые корки/яблочный жмых	Хороший кислородный барьер; перспективен для активных плёнок	Ограниченный влагобарьер; требует модификации/композитов	[68, 72]
PHA (ПГА)	Микробный полиэстер	Хорошие барьерные свойства, биоразложение	Высокая себестоимость производства	[14]
Альгинат	Бурые водоросли	Нетоксичен, плёнкообразование	Ограниченный барьер к водяному пару	[14, 16]
Целлюлоза/наноцеллюлоза	Растения/агроотходы	Усиление композитов, низкая газопроницаемость	Гидрофильность; совместимость с матрицей	[14, 71, 72, 74]

Примечание. Реальные свойства определяются рецептурой (смеси, пластификаторы, наполнители), технологией формирования и условиями применения/утилизации.

3. Циркулярная биоэкономика в послеуборочной цепочке: ресурсные потоки, технологии извлечения и оценка воздействия

Переход к циркулярной биоэкономике в плодоовощном секторе предполагает рассмотрение послеуборочной цепочки как системы взаимосвязанных потоков, где наряду с товарной продукцией формируются побочные фракции (очистки, кожура, жмых, несорт, отходы калибровки и нарезки). В устойчивой модели такие потоки целесообразно трактовать как вторичное сырьё для получения ингредиентов с добавленной стоимостью и как резерв снижения экологической нагрузки за счёт уменьшения объёмов захоронения и потерь. Актуальность ресурсного подхода усиливается масштабом пищевых потерь и целевыми ориентирами по их сокращению к 2030 году. В практическом плане это требует не только количественной оценки образующихся побочных потоков, но и их технологической паспортизации (вариабельность состава, микробиологическое состояние, стабильность при хранении), поскольку именно эти параметры определяют реализуемость каскадных схем переработки. Показано, что побочные продукты отдельных культур могут быть богаты фенольными соединениями (в том числе антоцианами, лютеолином, кверцетином, катехинами) и хлорофиллом, что делает их перспективными источниками функциональных компонентов; однако переход к промышленным решениям требует дальнейшей фитохимической и биологической валидации, а также масштабирования и клинической проверки заявляемых эффектов [75].

Технологии извлечения

Инструментарий циркулярной модели включает как традиционные методы экстракции, так и физические способы интенсификации, ориентированные на снижение ресурсоёмкости и повышение выхода целевых веществ. Среди таких решений широко обсуждается ультразвук, который может сокращать продолжительность операций, повышать эффективность извлечения и уменьшать расход растворителей, а также использоваться как предварительная обработка перед сушкой и в отдельных режимах способствовать снижению микробной нагрузки [76]. Его ценность в рамках циркулярности состоит в том, что технология одновременно поддерживает задачи сохранения качества и задачи выделения биоактивных соединений из вторичных потоков, повышая общую эффективность переработки. В более широком контексте устойчивой переработки предлагается различать «концевые» решения и чистые (превентивные) техноло-

гии, соотнося последние с подходом ЮНЕП, ориентированным на предотвращение загрязнений и рост экологической эффективности [77]. На основе строгого отбора публикаций устойчивые технологические меры группируются по четырём направлениям: снижение выбросов CO_2 замещение материалов/топлива, повышение энерго- и материалоэффективности и переработка [78]. Отмечается, что скорость внедрения определяется не только технологической готовностью, но и регуляторными стимулами, характеристиками компаний, уровнем технологических компетенций, наличием сертифицированных систем управления и межорганизационным сотрудничеством [78].

Оценка воздействия на здоровье

Развитие циркулярной биоэкономики требует расширения критериев оценки технологий: наряду с выходом продукта и сохранностью качества необходимо учитывать последствия по жизненному циклу (энергозатраты, эмиссии, расход воды и растворителей, образование вторичных отходов, сценарии утилизации). Дополнительный слой сложности связан с оценкой потенциальных эффектов для здоровья в ситуациях, когда биоактивные компоненты из побочных потоков используются для модификации пищевых матриц. Эта проблема наиболее заметна в дискуссии об ультрапереработанных продуктах, где вклад собственно технологической обработки в неблагоприятные исходы для здоровья остаётся недостаточно определённым, а попытки обогащения рецептур ингредиентами из вторичных ресурсов усложняют интерпретацию. В обзоре Капоцци и соавт. подчёркивается необходимость переоценки доказательной базы и развития новых парадигм оценки, которые учитывают параметры обработки и биологические механизмы (включая подходы инженерной геномики, анализ сигнальных путей и принципы точного питания) и опираются на цифровые инструменты и междисциплинарное взаимодействие науки и индустрии [5]. В целом циркулярная биоэкономика рассматривается как системная рамка, позволяющая преобразовывать агропродовольственные потоки в функциональные ингредиенты и продукты с добавленной стоимостью при одновременном снижении экологической нагрузки; при этом существенное значение имеют поддерживающая политика, нормативно-правовые условия и потребительский спрос на экологичные решения [79].

Таблица 3.

Сопоставление решений в логике циркулярной биоэкономики (потоки–технологии–оценка воздействия)

Блок	Объект сравнения	Цель	Основные показатели	Ограничения внедрения
Ресурсные потоки	Побочные продукты плодоовощной переработки (кожура, жмых, несорт и др.)	Снижение потерь, формирование сырья для функциональных ингредиентов	выход целевых фракций; стабильность состава; микробиологические показатели; доля утилизируемого потока	вариабельность сырья; сезонность; логистика и хранение побочных потоков
Технологии извлечения	Ультразвук как интенсификация экстракции/предобработка	Рост выхода экстракции, сокращение времени, снижение расхода растворителя/энергии	выход экстракта; время процесса; расход растворителя; энергозатраты; сохранность биоактивных веществ	нехватка стандартизированных режимов; ограниченность пилотных данных; сложность масштабирования для разных матриц
Технологические стратегии	Чистые (превентивные) технологии vs «концевые» меры	Профилактика загрязнений и повышение эффективности вместо компенсации последствий	удельные выбросы CO_2; энерго- и материалоёмкость; доля переработки; замещение материалов/топлива	регуляторные и организационные барьеры; потребность в кооперации и сертификации
Оценка воздействия	Экологический и «здоровьесберегающий» контур (LCA + питание/здоровье)	Сопоставимость решений по жизненному циклу и потенциальным эффектам для здоровья	LCA-метрики (энергия/выбросы/вода); безопасность при контакте с пищей; нутриентный профиль; биодоступность	

Выводы и перспективы

Максимальное сокращение послеуборочных потерь свежих плодов и овощей — один из ключевых факторов устойчивости агропродовольственного сектора. Потери означают не только недопоставку продукции, но и рост экологического следа за счёт «потраченных впустую» воды, энергии и связанных выбросов, что особенно критично в условиях климатических рисков. Современное послеуборочное управление всё чаще строится на сочетании передовых способов обработки, энергоэффективного (в том числе интеллектуального) хранения и более экологичных упаковочных решений. Важной тенденцией является замещение нефтехимических пластмасс биоразлагаемыми биополимерами и биокомпозитами из возобновляемого сырья.

Однако массовое внедрение ограничивают стоимость, трудности масштабирования, различия в нормативных требованиях и неоднозначное потребительское восприятие. Долгосрочная эффективность обеспечивается не отдельными технологиями, а интегрированной стратегией, основанной на принципах циркулярной биоэкономики: предотвращение потерь, вовлечение побочных продуктов в переработку и получение ценных компонентов, а также обязательное соблюдение требований безопасности материалов, контактирующих с пищей. В качестве приоритетов на перспективу выделяются: гармонизация регулирования биоразлагаемой упаковки, инвестиции в инфраструктуру (особенно для стран с низким и средним доходом), развитие междисциплинарных проектов и создание систем поддержки решений, объединяющих **оценку жизненного цикла,** методы ИИ и подходы точного питания. Комплексная реализация этих направлений способствует достижению ЦУР 12.3, снижает нагрузку на окружающую среду и повышает устойчивость глобальной продовольственной системы.

Список литературы

1. Бурак, Л. Ч. Влияние современных способов обработки и стерилизации на качество плодоовощного сырья и соковой продукции // Москва : Общество с ограниченной ответственностью «Научно-издательский центр ИНФРА-М», 2025. 236 с. https://doi.org/10.12737/0.12737/2154991
2. Ullah Q., Waqar M., Sajjad N., et al. Innovative Strategies for Postharvest Disease Management in Fruits and Vegetables: A Comprehensive Treatise // Food Science & Nutrition. 2025. V. 13. p. e70850. https://doi.org/10.1002/fsn3.4473
3. Palumbo M., Attolico G., Capozzi V., et al. Emerging postharvest technologies to enhance the shelf-life of fruit and vegetables: An overview // Foods. 2022. V. 11, no. 23. p. 3925. https://doi.org/10.3390/foods11233925
4. Oyewole O.S., Raji M.A., Kazeem A.A., et al. Smart technological innovations for postharvest loss reduction: A review // FUDMA Journal of Sciences. 2025. V. 9, no. 1. p. 299–307. https://doi.org/10.33003/fjs-2025-0901-299
5. Verma S., Kumar S., Kumar V., et al. Recent Advancements and Innovations in Post-harvest Handling, Storage, and Technology for Vegetables: A Review // Archives of Current Research International. 2025. V. 25, no. 1. p. 161–180. https://doi.org/10.9734/acri/2025/v25i1742
6. Бурак, Л. Ч., Овсянникова Н. Л. Современные способы хранения и упаковки земляники садовой (Fragaria × ananassa Duch.) (обзор) // Современное садоводство. 2024. № 3. С. 34-54
7. Capozzi F., Magkos F., Fava F., et al. A Multidisciplinary Perspective of Ultra-Processed Foods and Associated Food Processing Technologies: A View of the Sustainable Road Ahead // Nutrients. 2021. V. 13, no. 11. p. 3948. https://doi.org/10.3390/nu13113948
8. Ashraf M.A., Khan A.S., Azam M., et al. Innovative technologies in postharvest management of fruits and vegetables: A review // European Food Research and Technology. 2025. V. 251. p. 3445–3463. https://doi.org/10.1007/s00217-024-04620-3
9. Бурак, Л. Ч., Сапач А.Н. Влияние предварительной обработки импульсным электрическим полем на процесс сушки: обзор предметного поля // Хранение и переработка сельхозсырья. 2023. № 2. С. 44-71 https://doi.org/10.36107/spfp.2023.418
10. Бурак, Л. Ч. Использование современных технологий обработки для увеличения срока хранения фруктов и овощей. Обзор предметного поля // Ползуновский вестник. 2024. № 1. С. 99-119. https://doi.org/10.25712/ASTU.2072-8921.2024.01.013
11. Sibanda S., Workneh T.S. Potential causes of postharvest losses, low-cost cooling technology for fresh produce farmers in Sub-Sahara Africa // African Journal of Agricultural Research. 2020. V. 16, no. 4. p. 553–566. https://doi.org/10.5897/AJAR2019.14501
12. Nguyen A.T., Parker L., Brennan L., Lockrey S. A consumer definition of eco-friendly packaging // Journal of Cleaner Production. 2020. V. 252. p. 119792. https://doi.org/10.1016/j.jclepro.2019.119792
13. Khandeparkar A.S., Paul R., Sridhar A., et al. Eco-friendly innovations in food packaging: A sustainable revolution // Sustainable Chemistry and Pharmacy. 2024. V. 39. p. 101579. https://doi.org/10.1016/j.scp.2024.101579
14. Бурак, Л. Ч., Сапач А.Н. Использование технологии омического нагрева в процессе переработки плодов и овощей. Обзор предметного поля // Пищевые системы. 2024. Т. 7, № 1. С. 59-70 https://doi.org/10.21323/2618-9771-2024-7-1-59-70
15. Kumar S., Mukherjee A., Dutta J. Chitosan based nanocomposite films and coatings: Emerging antimicrobial food packaging alternatives // Trends in Food Science & Technology. 2020. V. 97. p. 196–209. https://doi.org/10.1016/j.tifs.2020.01.002
16. Ayyub S., Khan A.S., Anwar R., et al. Aloe vera gel coating extends marketability and maintains quality by reducing rachis Browning and preserving bioactive compounds of commercial table grape cultivars // Applied Fruit Science. 2024. V. 66. p. 1843–1853. https://doi.org/10.1007/s10341-024-01102-1
17. Бурак, Л. Ч. Обзор разработок биоразлагаемых упаковочных материалов для пищевой промышленности // Ползуновский вестник. 2023. № 1. С. 91-105. https://doi.org/10.25712/ASTU.2072-8921.2023.01.012
18. Matloob A., Ayub H., Mohsin M., et al. A review on edible coatings and films: Advances, composition, production methods, and safety concerns // ACS Omega. 2023. V. 8, no. 31. p. 28932–28944. https://doi.org/10.1021/acsomega.3c03498
19. Fan X., Wang W. Quality of Fresh and Fresh-Cut Produce Impacted by Nonthermal Physical Technologies Intended to Enhance Microbial Safety // Critical Reviews in Food Science and Nutrition. 2022. V. 62, no. 2. p. 362–382. https://doi.org/10.1080/10408398.2020.1814196
20. Бурак, Л. Ч., Сапач А.Н., Писарик М.И. Влияние ультразвука на процесс замораживания и

качество замороженных фруктов и овощей // Вестник Международной академии холода. 2024. № 1. С. 71-78. https://doi.org/10.17586/1606-4313-2024-23-1-71-78

21. Ganesan A.R., Tiwari U., Ezhilarasi P.N., Rajauria G. Application of Cold Plasma on Food Matrices: A Review on Current and Future Prospects // Journal of Food Processing and Preservation. 2021. V. 45, no. 1. p. e15070. https://doi.org/10.1111/jfpp.15070

22. Rux G., Gelewsky R., Schlüter O., Herppich W.B. High Hydrostatic Pressure Treatment Effects on Selected Tissue Properties of Fresh Horticultural Products // Innovative Food Science & Emerging Technologies. 2020. V. 61. p. 102326. https://doi.org/10.1016/j.ifset.2020.102326

23. Hu X., Ma T., Ao L., et al. Effect of High Hydrostatic Pressure Processing on Textural Properties and Microstructural Characterization of Fresh-cut Pumpkin (Cucurbita pepo) // Journal of Food Process Engineering. 2020. V. 43, no. 4. p. e13379. https://doi.org/10.1111/jfpe.13379

24. Hu K., Peng D., Wang L., et al. Effect of Mild High Hydrostatic Pressure Treatments on Physiological and Physicochemical Characteristics and Carotenoid Biosynthesis in Postharvest Mango // Postharvest Biology and Technology. 2021. V. 172. p. 111381. https://doi.org/10.1016/j.postharvbio.2020.111381

25. Kundukulangara Pulissery S., Kallahalli Boregowda S., Suseela S., Jaganath B.A. Comparative Study on the Textural and Nutritional Profile of High Pressure and Minimally Processed Pineapple // Journal of Food Science and Technology. 2021. V. 58, no. 10. p. 3734–3742. https://doi.org/10.1007/s13197-020-04831-2

26. Paciulli M., Ganino T., Meza I.G.M., et al. High Pressure and Thermal Processing on the Quality of Zucchini Slices // European Food Research and Technology. 2021. V. 247. p. 475–484. https://doi.org/10.1007/s00217-020-03640-x

27. Li J., Shi J., Huang X., et al. Effects of Pulsed Electric Field Pretreatment on Frying Quality of Fresh-Cut Lotus Root Slices // LWT. 2020. V. 132. p. 109873. https://doi.org/10.1016/j.lwt.2020.109873

28. López-Gámez G., Elez-Martínez P., Martín-Belloso O., Soliva-Fortuny R. Pulsed Electric Fields Affect Endogenous Enzyme Activities, Respiration and Biosynthesis of Phenolic Compounds in Carrots // Postharvest Biology and Technology. 2020. V. 168. p. 111284.
https://doi.org/10.1016/j.postharvbio.2020.111284

29. López-Gámez G., Elez-Martínez P., Martín-Belloso O., Soliva-Fortuny R. Changes of Carotenoid Content in Carrots after Application of Pulsed Electric Field Treatments // LWT. 2021. V. 147. p. 111408. https://doi.org/10.1016/j.lwt.2021.111408

30. Vanga S.K., Wang J., Jayaram S., Raghavan V. Effects of Pulsed Electric Fields and Ultrasound Processing on Proteins and Enzymes: A Review // Processes. 2021. V. 9, no. 4. p. 722. https://doi.org/10.3390/pr9040722

31. Бурак Л.Ч., Сапач А.Н., Завалей А.П. Влияние обработки холодной плазмой на качество и пищевую ценность растительного сырья. Обзор предметного поля // Известия вузов. Прикладная химия и биотехнология. 2024. 14, 2. 173–183 https://doi.org/10.21285/achb.914

32. Bagheri H., Abbaszadeh S. Effect of Cold Plasma on Quality Retention of Fresh-Cut Produce // Journal of Food Quality. 2020. V. 2020. p. 8866369. https://doi.org/10.1155/2020/8866369

33. Zhou D., Li T., Cong K., Suo A., Wu C. Influence of Cold Plasma on Quality Attributes and Aroma Compounds in Fresh-Cut Cantaloupe during Low Temperature Storage // LWT. 2022. V. 154. p. 112893. https://doi.org/10.1016/j.lwt.2021.112893

34. Ahmadnia M., Sadeghi M., Abbaszadeh R., Ghomi Marzdashti H.R. Decontamination of Whole Strawberry via Dielectric Barrier Discharge Cold Plasma and Effects on Quality Attributes // Journal of Food Processing and Preservation. 2021. V. 45, no. 1. p. e15019. https://doi.org/10.1111/jfpp.15019

35. Rana S., Mehta D., Bansal V., Shivhare U.S., Yadav S.K. Atmospheric Cold Plasma (ACP) Treatment Improved in-Package Shelf-Life of Strawberry Fruit // Journal of Food Science and Technology. 2020. V. 57, no. 1. p. 102–112. https://doi.org/10.1007/s13197-019-04035-x

36. Zhang Y., Zhang J., Zhang Y., et al. Effects of In-package Atmospheric Cold Plasma Treatment on the Qualitative, Metabolic and Microbial Stability of Fresh-cut Pears // Journal of the Science of Food and Agriculture. 2021. V. 101, no. 11. p. 4473–4480. https://doi.org/10.1002/jsfa.11087

37. Giannoglou M., Stergiou P., Dimitrakellis P., et al. Effect of Cold Atmospheric Plasma Processing on Quality and Shelf-Life of Ready-to-Eat Rocket Leafy Salad // Innovative Food Science & Emerging Technologies. 2020. V. 66. p. 102502. https://doi.org/10.1016/j.ifset.2020.102502

38. Бурак Л. Ч., Сапач А.Н., Саманкова Н. В. Современные методы дезактивации афлатоксинов в пищевых продуктах // Научное обозрение. Биологические науки. 2024. № 4. С. 31-40. https://doi.org/10.17513/srbs.1383

39. Hu X., Sun H., Yang X., et al. Potential Use of Atmospheric Cold Plasma for Postharvest Preservation of Blueberries // Postharvest Biology and Technology. 2021. V. 179. p. 111564. https://doi.org/10.1016/j.postharvbio.2021.111564

40. Singh S.P., Thakur R. Postharvest applications of cold plasma treatment for improving food safety and sustainability outcomes for fresh horticultural produce // Postharvest Biology and Technology. 2024. V. 209. p. 112694.
https://doi.org/10.1016/j.postharvbio.2023.112694

41. Kitsiou M., Purk L., Ioannou C., et al. On the evaluation of the antimicrobial effect of grape seed extract and cold atmospheric plasma on the dynamics of Listeria monocytogenes in novel multiphase 3D viscoelastic models // International Journal of Food Microbiology. 2023. V. 406. p. 110395. https://doi.org/10.1016/j.ijfoodmicro.2023.110395

42. Бурак Л. Ч. Влияние электролизованной воды на качество и безопасность плодоовощного сырья // Научное обозрение. Биологические науки. 2024. № 3. С. 59-70. https://doi.org/10.17513/srbs.1375

43. Nikzadfar M., Kazemi A., Abooei R., et al. Application of cold plasma technology on the postharvest preservation of in packaged fresh fruit and vegetables: Recent challenges and development // Food and Bioprocess Technology. 2024. V. 17. p. 4473–4505. https://doi.org/10.1007/s11947-024-03387-z

44. Бурак Л. Ч., Сапач А.Н. Влияние действия ультразвука на функциональные свойства растительных белков. Обзор предметного поля // Химия растительного сырья. 2024. № 4. С. 5-23. https://doi.org/10.14258/jcprm.20240413599

45. Perinban S., Orsat V., Raghavan V. Influence of Plasma Activated Water Treatment on Enzyme Activity and Quality of Fresh-Cut Apples // Food Chemistry. 2022. V. 393. p. 133421. https://doi.org/10.1016/j.foodchem.2022.133421

46. Darré M., Vicente A.R., Cisneros-Zevallos L., Artés-Hernández F. Postharvest ultraviolet radiation in fruit and vegetables: Applications and factors modulating its efficacy on bioactive compounds and microbial growth // Foods. 2022. V. 11, no. 5. p. 653. https://doi.org/10.3390/foods11050653

47. Pizzichetti R., Martín-Gamboa M., Pablos C., et al. Environmental life cycle assessment of UV-C leds vs. mercury lamps and oxidant selection for diclofenac degradation // Sustainable Materials and Technologies. 2024. V. 41. p. e01002. https://doi.org/10.1016/j.susmat.2024.e01002

48. Kyere E.O., Popovich D.G., Palmer J., et al. Reduction of the attachment, survival and growth of Listeria monocytogenes on lettuce leaves by UV-C stress // LWT. 2021. V. 145. p. 111528. https://doi.org/10.1016/j.lwt.2021.111528

49. Phonyiam O., Ohara H., Kondo S., et al. Postharvest UV-C irradiation influenced cellular structure, jasmonic acid accumulation, and resistance against green mold decay in Satsuma Mandarin fruit (Citrus unshiu) // Frontiers in Sustainable Food Systems. 2021. V. 5. p. 684434. https://doi.org/10.3389/fsufs.2021.684434

50. Le T.T.N., Liao C.T., Wu C.S., et al. Can UVC radiation be useful in prolonging the shelf life of mangoes? // Smart Agricultural Technology. 2024. V. 9. p. 100612. https://doi.org/10.1016/j.atech.2024.100612

51. Ramalingam S., Le Myint Z., Ahn S.Y., et al. UV-C treatment elicits resistant responses against Botrytis cinerea infection and the improvement of fruit characteristics in grapevines // Horticulture, Environment, and Biotechnology. 2024. V. 65. p. 707–724. https://doi.org/10.1007/s13580-024-00610-1

52. Hwang H.J., Kim J.W., Choi J.B., Chung M.S. Effects of the specific wavelength and intensity of intense pulsed light (IPL) on microbial inactivation // Food and Bioprocess Technology. 2024. V. 18. p. 1719–1729. https://doi.org/10.1007/s11947-024-03460-7

53. Бурак Л. Ч. Ультрапереработанные продукты питания: методы снижения их калорийности и повышения пищевой ценности (Обзор предметного поля) // Health, Food & Biotechnology. 2025. Т. 7, № 2. С. 41-75. https://doi.org/10.36107/hfb.2025.i2.s258

54. Vargas-Ramella M., Pateiro M., Gavahian M., et al. Impact of pulsed light processing technology on phenolic compounds of fruits and vegetables // Trends in Food Science & Technology. 2021. V. 115. p. 1–11. https://doi.org/10.1016/j.tifs.2021.06.017

55. Yao J., Chen W., Fan K. Recent advances in light irradiation for improving the preservation of fruits and vegetables: A review // Food Bioscience. 2023. V. 56. p. 103206. https://doi.org/10.1016/j.fbio.2023.103206

56. Pinto L., Cefola M., Bonifacio M.A., et al. Effect of red thyme oil (Thymus vulgaris L.) vapours on fungal decay, quality parameters and shelf-life of oranges during cold storage // Food Chemistry. 2021. V. 336. p. 127590. https://doi.org/10.1016/j.foodchem.2020.127590

57. Pinto L., Palma A., Cefola M., Pace B., D'Aquino S., Carboni C., Baruzzi F. Effect of modified atmosphere packaging (MAP) and gaseous ozone pre-packaging treatment on the physico-chemical, microbiological, and sensory quality of small fruit // Food Packaging and Shelf Life. 2020. V. 26. p. 100573. https://doi.org/10.1016/j.fpsl.2020.100573

58. Singla M., Sit N. Application of Ultrasound in Combination with other Technologies in Food Processing: A Review // Ultrasonics Sonochemistry. 2021. V. 73. p. 105506. https://doi.org/10.1016/j.ultsonch.2021.105506

59. Бурак, Л. Ч., Сапач А.Н., Лукин А. А. Современные методы предварительной обработки для повышения качества и пищевой ценности сухофруктов: обзор // Инновации и продовольственная безопасность. 2025. № 4(50). С. 8-42. https://doi.org/10.31677/2311-0651-2025-50-4-8-42

60. Starek A., Kobus Z., Sagan A., et al. Influence of ultrasound on selected microorganisms, chemical and structural changes in fresh tomato juice // Scientific Reports. 2021. V. 11. p. 3488. https://doi.org/10.1038/s41598-021-83141-w

61. Darsana K., Sivakumar P. Potential of Ultrasound in Food Processing: An Overview // Current Journal of Applied Science and Technology. 2023. V. 42, no. 1. p. 14–34. https://doi.org/10.9734/cjast/2023/v42i14013

62. Бурак Л. Ч., Востриков А. В. Использование технологии каталитического инфракрасного излучения при переработке плодоовощного сырья. Обзор предметного поля // Научное обозрение. Технические науки. 2024. № 4. С. 21-34. https://doi.org/10.17513/srts.1479

63. Kumar K., Srivastav S., Sharanagat V.S. Ultrasound assisted extraction (UAE) of bioactive compounds from fruit and vegetable processing by-products: A review // Ultrasonics Sonochemistry. 2020. V. 70. p. 105325. https://doi.org/10.1016/j.ultsonch.2020.105325

64. Perera C.O., Alzahrani M.A.J. Ultrasound as a pre-treatment for extraction of bioactive compounds and food safety: A review // LWT. 2021. V. 142. p. 111114. https://doi.org/10.1016/j.lwt.2021.111114

65. Gupta A.K., Sahu P.P., Mishra P. Ultrasound aided debittering of bitter variety of citrus fruit juice: Effect on chemical, volatile profile and antioxidative potential // Ultrasonics Sonochemistry. 2021. V. 81. p. 105839. https://doi.org/10.1016/j.ultsonch.2021.105839

66. Esteban-Lustres R., Sanz V., Domínguez H., Torres M.D. Ultrasound-Assisted Extraction of High-Value Fractions from Fruit Industrial Processing Waste // Foods. 2022. V. 11, no. 14. p. 2089. https://doi.org/10.3390/foods11142089

67. Kruszewski B., Boselli E. Blackcurrant Pomace as a Rich Source of Anthocyanins: Ultrasound-Assisted Extraction under Different Parameters // Applied Sciences. 2024. V. 14, no. 2. p. 821. https://doi.org/10.3390/app14020821

68. Бурак Л. Ч. Перспективы использования технологии сверхкритического диоксида углерода в пищевой промышленности. Обзор предметного поля // Ползуновский вестник. 2025. № 1. С. 32-50. https://doi.org/10.25712/ASTU.2072-8921.2025.01.004

69. Silva J.V.M., Santos A.S., Pereira G.A., Chisté R.C. Ultrasound-assisted extraction using ethanol efficiently extracted carotenoids from peels of peach palm fruits (Bactris gasipaes Kunth) without altering qualitative carotenoid profile // Heliyon. 2023. V. 9, no. 3. p. e14933. https://doi.org/10.1016/j.heliyon.2023.e14933

70. Бурак Л. Ч., Сапач А.Н., Писарик М.И. Интеллектуальная упаковка для овощей и фруктов, классификация и перспективы использования: Обзор предметного поля // Health, Food & Biotechnology. 2023. Т. 5, № 1. С. 51-80. https://doi.org/10.36107/hfb.2023.i1.s165

71. Bhargava N., Mor R.S., Kumar K., Sharanagat V.S. Advances in application of ultrasound in food processing: A review // Ultrasonics Sonochemistry. 2021. V. 70. p. 105293. https://doi.org/10.1016/j.ultsonch.2020.105293

72. Бурак Л. Ч. Ограничения и возможности современных технологий обеспечению микробиологической безопасности пищевых продуктов // Известия высших учебных заведений. Пищевая технология. 2024. № 2-3(396). С. 6-13. https://doi.org/10.26297/0579-3009.2024.2-3.1

73. Khalil R.K.S., Sharaby M.R., Abdelrahim D.S. Novel active edible food packaging films based entirely on citrus peel wastes // Food Hydrocolloids. 2023. V. 134. p. 107961. https://doi.org/10.1016/j.foodhyd.2022.107961

74. Бурак Л. Ч., Завалей А.П., Сапач А. Н. Эффективность комбинированного воздействия ультразвука и микроволн при обработке пищевых продуктов. Обзор // Техника и технология пищевых производств. 2024. Т. 54, № 2. С. 342-357. https://doi.org/10.21603/2074-9414-2024-2-2510

75. Sathish Kumar R.K., Dhilipkumar T., Anita Jessie J., et al. Advancements in bio-polymeric composite materials for active and intelligent food packaging: A comprehensive review // Materials Today: Proceedings. 2023. https://doi.org/10.1016/j.matpr.2023.04.145

76. Mgoma S.T., Basitere M., Mshayisa V.V., De Jager D. A Systematic Review on Sustainable Extraction, Preservation, and Enhancement in Food Processing: The Advancement from Conventional to Green Technology Through Ultrasound // Processes. 2025. V. 13, no. 7. p. 965. https://doi.org/10.3390/pr13070965

77. Бурак Л. Ч., Ермошина Т.В., Саманкова Н. В. Устойчивое производство. Концепция качества 4.0 // Фундаментальные исследования. 2025. № 9. С. 81-90. https://doi.org/10.17513/fr.43905

78. Mady N.E., Hashem M.M., Khallaf I.S.A., et al. From waste to health: A review on benefits of certain food by-products // Discover Applied Sciences. 2025. V. 7. p. 1008. https://doi.org/10.1007/s42452-024-06398-4

79. Бурак, Л. Ч., Ермошина Т.В., Саманкова Н. В. Достижение устойчивого развития за счет использования новых технологий переработки пищевых продуктов // Фундаментальные исследования. 2024. № 10. С. 171-179. https://doi.org/10.17513/fr.43705

СРАВНЕНИЕ УСТОЙЧИВОСТИ ВЕРОЯТНОСТНЫХ ID-МОДЕЛЕЙ В УСЛОВИЯХ СТРОГОГО СОБЛЮДЕНИЯ ТРЕБОВАНИЙ К КОНФИДЕНЦИАЛЬНОСТИ

Рог К.
менеджер по управлению доходностью, Cadent,
Соединенные Штаты Америки, г. Нью-Йорк

COMPARISON OF THE STABILITY OF PROBABILISTIC ID MODELS IN CONDITIONS OF STRICT COMPLIANCE WITH CONFIDENTIALITY REQUIREMENTS

Roh K.
Yield Manager, Cadent,
United States, New York
DOI: 10.5281/zenodo.18614953

Аннотация

В статье рассматривается устойчивость вероятностных ID-моделей (probabilistic ID), применяемых в AdTech и programmatic-закупках для вероятностной идентификации и связывания пользовательских сигналов (identity resolution) в условиях усиления требований к конфиденциальности. Обосновано, что приватностные ограничения (минимизация признаков, деидентификация, агрегирование и добавление случайности, включая механизмы дифференциальной приватности) изменяют информационную среду модели и могут снижать стабильность вероятностных оценок и пороговых решений при колебаниях качества данных и сдвиге распределений. Предложена рамка сравнения устойчивости, включающая воспроизводимый протокол подготовки и сопоставления записей, моделирование типовых ухудшений данных (рост пропусков, шум, разреженность) и статистическое сопоставление моделей по интегральным метрикам качества и показателям калибровки с оценкой неопределённости. Практическая значимость работы состоит в формировании подхода к выбору и настройке probabilistic ID-моделей, обеспечивающих воспроизводимость маркетинговых оценок (охват/частота, дедупликация, атрибуция, измерение эффективности) при ограниченном доступе к идентификаторам.

Abstract

The article examines the stability of probabilistic ID models used in AdTech and programmatic procurement for probabilistic identification and user signal binding (identity resolution) in the context of increased confidentiality requirements. It is proved that privacy constraints (feature minimization, de-identification, aggregation and addition of randomness, including mechanisms of differential privacy) change the information environment of the model and can reduce the stability of probabilistic estimates and threshold solutions with fluctuations in data quality and shifting distributions. A stability comparison framework is proposed that includes a reproducible protocol for preparing and comparing records, modeling typical data degradation (increased gaps, noise, sparsity), and statistical comparison of models using integral quality metrics and calibration indicators with uncertainty estimation. The practical significance of the work lies in the formation of an approach to the selection and configuration of probabilistic ID models that ensure reproducibility of marketing estimates (coverage/frequency, deduplication, attribution, performance measurement) with limited access to identifiers.

Ключевые слова: probabilistic ID, identity resolution, record linkage, programmatic, AdTech, устойчивость, конфиденциальность персональных данных, деидентификация, дифференциальная приватность, минимизация данных, сдвиг распределения данных, калибровка вероятностей, дедупликация охвата, охват и частота, атрибуция.

Keywords: probabilistic ID, identity resolution, record linkage, programmatic, AdTech, sustainability, confidentiality of personal data, deidentification, differential privacy, data minimization, data distribution shift, probability calibration, coverage deduplication, coverage and frequency, attribution.

Актуальность исследования

Актуальность исследования обусловлена тем, что вероятностные ID-модели (модели идентификации, верификации и сопоставления записей по вероятностным признакам) всё шире применяются в цифровых сервисах, где корректность установления идентичности и связности данных напрямую влияет на качество управленческих, финансовых и организационных решений. Одновременно усиливаются требования к конфиденциальности персональных данных и ограничения на их сбор, хранение и обработку: организации вынуждены минимизировать объём доступной информации и ограничивать передачу данных между контурами. В таких условиях даже качественно построенная ID-модель может демонстрировать нестабильное поведение при неизбежных изменениях входных данных и условий эксплуатации, что повышает риск ошибок идентификации, необоснованных отказов, неверной сегментации пользователей или некорректной оценки рисков.

Особую значимость приобретает именно устойчивость вероятностных ID-моделей, понимаемая как способность сохранять предсказуемое качество и корректность вероятностных выводов при вариациях данных, признакового пространства и распределений (например, при сдвиге данных во времени, разреженности наблюдений, неполноте профилей, добавлении шума, изменении источни-

ков). Строгое соблюдение требований к конфиденциальности само по себе изменяет информационную среду модели: сокращается число признаков, возрастает доля пропусков, вводятся механизмы защиты (ограничение детализации, агрегирование, добавление случайности, распределённая обработка), что может по-разному влиять на устойчивость разных классов вероятностных моделей. В результате на практике возникает методологическая проблема: выбор ID-модели по среднему качеству на «удобных» данных не гарантирует надёжности в приватностно-ограниченной среде, где важны не только точность, но и стабильность поведения при допустимых преобразованиях данных.

Следовательно, научно и практически востребовано сопоставление устойчивости вероятностных ID-моделей именно в режимах строгой конфиденциальности: такое сравнение позволяет выявить модели, которые сохраняют приемлемое качество при приватностных ограничениях, формализовать компромисс «качество – конфиденциальность – устойчивость», а также предложить обоснованные критерии выбора и настройки решений для реальных систем. Это повышает доверие к идентификационным механизмам, снижает риски ошибочных решений и способствует построению воспроизводимых и контролируемых процедур обработки данных, соответствующих требованиям конфиденциальности.

Цель исследования

Цель данного исследования – сопоставить устойчивость вероятностных ID-моделей в условиях строгого соблюдения требований к конфиденциальности и определить критерии выбора и настройки моделей, обеспечивающих предсказуемое качество при ограничениях на признаки и при типовых изменениях качества данных.

Материалы и методы исследования

Материалами исследования выступают научные публикации по вероятностному связыванию записей и устойчивости алгоритмов, а также открытые нормативно-методические источники по конфиденциальности обработки персональных данных.

Методика включает: унифицированную схему связывания записей; моделирование воспроизводимых сценариев изменения данных; оценку качества по пороговым метрикам и интегральным показателям и оценку качества вероятностных прогнозов по показателям калибровки; статистическое сопоставление результатов на повторениях с построением доверительных интервалов для ключевых метрик.

Результаты исследования

В маркетинге и рекламных технологиях идентификатор выполняет функцию технического ключа, необходимого для расчёта охвата и частоты, управления экспозицией и измерения эффективности коммуникаций. В условиях сокращения доступности прямых идентификаторов (cookies, MAID) и усиления privacy-ограничений значительная часть задач измерения и управления контактами переносится в область вероятностной идентификации. В таком подходе разрозненные сигналы (контекст, характеристики устройства и среды, сетевые и поведенческие паттерны, агрегированные события) используются для оценки вероятности того, что наблюдаемые события относятся к одному пользователю или домохозяйству.

Для programmatic-закупок и сквозной аналитики устойчивость (robustness) probabilistic ID-моделей является критическим свойством. Вариативность оценок совпадения при допустимых изменениях качества данных и приватностных преобразованиях приводит к нестабильной дедупликации, смещению распределений частоты, ошибкам сегментации и, как следствие, к колебаниям оценок эффективности при неизменной структуре медиаплана. Иными словами, управленческие выводы могут меняться не из-за реальных изменений поведения аудитории или медийного воздействия, а вследствие нестабильности идентификационного слоя (ID-графа). Наиболее типичные проявления таких эффектов и связанные с ними бизнес-риски представлены в таблице 1.

Таблица 1

Влияние нестабильности ID-слоя на аналитику и бизнес-риски

Параметр устойчивости ID-слоя	**Что нарушается в маркетинговой аналитике**	**Типичный риск для бизнеса**
Смещение порогов совпадения / несовпадения	Дедупликация охвата и оценка частоты начинают систематически дрейфовать	Перерасход бюджета, рост раздражения аудитории
Недостаточная калибровка вероятностей	Ошибки в построении аудиторий и ретаргетинге, ухудшение точности сегментации	Падение ROI, риски brand safety
Высокая вариативность при шуме и пропусках	Нестабильность атрибуции, MMM и оценок инкрементальности	Неверные решения о перераспределении бюджета

Источник: разработка автора.

В прикладных задачах programmatic-маркетинга ошибки вероятностной идентификации интерпретируются через влияние на ключевые KPI. Ложно-положительные совпадения (FP) приводят к объединению разных пользователей в один профиль, что занижает оценку охвата и искажает дедупликацию, а также может преждевременно ограничивать показы при frequency capping. Ложно-отрицательные ошибки (FN), напротив, «дробят» одного пользователя на несколько идентификаторов, завышая уникальный охват и повышая фактическую частоту контактов. В измерении эффективно-

сти mismatch связей между экспозициями и конверсиями снижает долю корректно сопоставленных цепочек событий, что уменьшает наблюдаемое число конверсий и приводит к смещению атрибуции и оценок инкрементальности. Следовательно, нестабильность ID-графа выражается не только в изменении метрик качества связывания, но и в вариативности маркетинговых оценок, поэтому устойчивость модели рассматривается как критерий воспроизводимости управленческих выводов.

Представленные эффекты задают прикладную мотивацию, однако их анализ требует формализации того, как именно строится вероятностная идентификация и в каких элементах процедуры возникают чувствительность и нестабильность.

Вероятностные ID-модели опираются на идею сопоставления объектов (записей) по набору наблюдаемых признаков с явным учётом неопределённости. Классическая статистическая постановка вероятностного связывания записей описана в работе И. Феллеги и А. Сантера: для каждой пары записей рассматриваются результаты сравнения полей (например, совпало/не совпало/частично совпало), задаются вероятности наблюдать такие результаты при истинном совпадении и при несовпадении, после чего рассчитывается суммарная оценка, а решения принимаются по порогам (совпадение, несовпадение и зона неопределённости) [1]. На практике к вероятностным ID-подходам относят и байесовские модели сопоставления, где оценка принадлежности пар одному объекту формулируется как апостериорная вероятность с учётом априорных предположений о частотах, ошибках ввода и пропусках; общим остаётся принцип: вероятность трактуется не как «уверенность», а как формализованная мера неопределённости, которая должна быть сопоставима между группами данных и сценариями применения.

Понятие устойчивости для вероятностных ID-моделей связано с предсказуемостью их выводов при допустимых изменениях данных и условий эксплуатации. В теории обучения устойчивость часто рассматривают через чувствительность алгоритма к изменению обучающей выборки и связь этой чувствительности с обобщающей способностью; в прикладных задачах идентификации дополнительно существенна устойчивость пороговых решений и калибровка вероятностей, то есть сохранение сопоставимого смысла вероятностных оценок при изменении распределений признаков. Отдельная причина неустойчивости – сдвиг данных, когда статистические свойства входов и/или связь между входами и целевой переменной отличаются между обучением и применением; для задач сопоставления это проявляется, например, при изменении качества заполнения полей, состава источников или частоты ошибок [2].

Строгое соблюдение требований к конфиденциальности ограничивает объём и детализацию доступной информации и тем самым меняет условия работы вероятностных ID-моделей. Для деидентификации применяются техники, описанные и классифицированные в ISO/IEC 20889. Формальные гарантии при публикации статистик и построении моделей обеспечивает дифференциальная приватность: она требует, чтобы распределение результатов анализа было практически одинаковым независимо от присутствия или отсутствия одной записи; на практике это достигается добавлением калиброванного шума и расходованием «бюджета приватности» (ε). Эти меры, как правило, уменьшают информативность признаков и/или повышают случайную вариативность оценок, из-за чего вероятности совпадения и пороговые решения в ID-задачах могут становиться менее стабильными при изменении данных.

Влияние приватностных ограничений на данные и устойчивость вероятностных ID-моделей показано в таблице 2.

Таблица 2

Влияние приватностных ограничений на данные и устойчивость вероятностных ID-моделей

Ограничение приватности	**Типичное изменение данных**	**Какой аспект устойчивости ID-модели затрагивается**
Обобщение / подавление (деидентификация)	Укрупнение категорий, пропуски, снижение уникальности комбинаций признаков	Рост неоднозначности, расширение «зоны неопределённости», сдвиг порогов решений
Рандомизация / шум (дифференциальная приватность)	Добавление случайности к статистикам / обновлениям / параметрам	Увеличение вариативности оценок, ухудшение калибровки вероятностей, чувствительность к настройкам приватности
Ограничение доступа и минимизация данных	Сокращение числа полей, запрет на «сильные» идентификаторы	Усиление зависимости от оставшихся признаков и от качества их заполнения; риск нестабильности при сдвиге данных

Источник: разработка автора.

Требования к конфиденциальности задают рамки того, какие данные допустимо собирать и как их можно использовать в эксперименте. При формировании ограничений экспериментального дизайна целесообразно опираться на базовые принципы обработки персональных данных, закреплённые в статье 5 GDPR. На рисунке 1 представлены эти принципы, которые задают «каркас» требова-

ний к данным и процедурам: обоснование цели обработки, минимизацию состава признаков, требования к точности и срокам хранения, а также обеспечение безопасности и подотчётности.

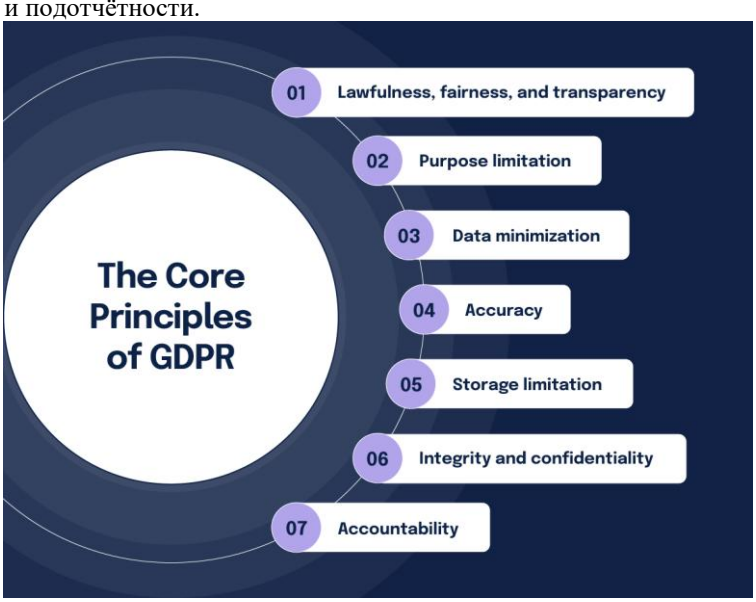


Рис. 1. Ключевые принципы обработки персональных данных в GDPR (статья 5): законность, справедливость и прозрачность; ограничение цели; минимизация данных; точность; ограничение хранения; целостность и конфиденциальность; подотчётность [4]

Эти принципы прямо превращаются в ограничения дизайна исследования: исключается использование «лишних» идентификаторов и полей «на всякий случай», требуется заранее фиксировать цель обработки и удерживать набор признаков минимально достаточным, а также обеспечивать режим доступа и защиты, исключающий несанкционированное раскрытие. Дополнительно в GDPR закреплена обязанность «защиты данных по замыслу и по умолчанию» (ст. 25), включая требование, чтобы по умолчанию обрабатывались только данные, необходимые для конкретной цели, и чтобы контролировались объём, срок хранения и доступность данных. Для проектов, способных повлечь высокий риск для прав и свобод, предусмотрена оценка воздействия на защиту данных (DPIA) до начала обработки (ст. 35 GDPR), что в экспериментальной постановке означает необходимость заранее документировать риски, меры защиты и обоснование выбора данных и методов (таблица 3).

Таблица 3

Принципы GDPR и соответствующие ограничения экспериментального дизайна при работе с персональными данными

Норма / принцип (источник)	**Проверяемое требование**	**Ограничение экспериментального дизайна (что нельзя / что обязательно)**
Ограничение цели (GDPR ст. 5)	Данные собираются для определённых целей	Фиксируется цель сравнения моделей и запрещается вторичное использование данных вне этой цели
Минимизация данных (GDPR ст. 5; разъяснения ICO)	Данные должны быть «адекватны, релевантны и ограничены необходимым»	Исключаются прямые идентификаторы и избыточные признаки; обосновывается каждый используемый признак
Целостность и конфиденциальность (GDPR ст. 5)	Обеспечиваются меры защиты от утечки / несанкционированного доступа	Работа в защищённом контуре, контроль доступа, запрет вывода индивидуальных записей и «сырых» предсказаний наружу
Защита по замыслу и по умолчанию (GDPR ст. 25)	«По умолчанию» обрабатывается только необходимое, ограничиваются доступность и сроки	Минимальные настройки доступа, ограничение журналирования, регламенты хранения / удаления экспериментальных наборов
DPIA (GDPR ст. 35; разъяснения DPA/ICO)	Оценка воздействия до обработки при высоком риске	Требуется документировать риски, меры снижения, критерии допустимости данных и протоколы тестирования

Источник: разработка автора.

Ограничения конфиденциальности относятся не только к исходным данным, но и к сведениям, которые могут быть раскрыты через работу модели и способы доступа к её результатам. В научной литературе описаны атаки, при которых по ответам модели пытаются установить, использовалась ли конкретная запись при обучении, либо восстановить чувствительные характеристики исходных данных. Поэтому при строгом соблюдении требований к конфиденциальности в экспериментальном дизайне, как правило, ограничивают состав и детализацию выдаваемых результатов (например, не публикуют оценки для отдельных записей), вводят разграничение прав доступа и контроль частоты запросов, а также исключают режимы, позволяющие массово опрашивать модель и извлекать информацию об обучающих данных.

Методика сравнения устойчивости вероятностных ID-моделей начинается с выбора общей, воспроизводимой схемы связывания записей: единые правила очистки и стандартизации полей, одинаковый механизм сокращения пространства пар (индексация/блокирование) и единый формат «вектора сравнений» признаков, после чего применяется выбранная вероятностная модель принятия решения о совпадении. На рисунке 2 представлен типовой процесс связывания записей.

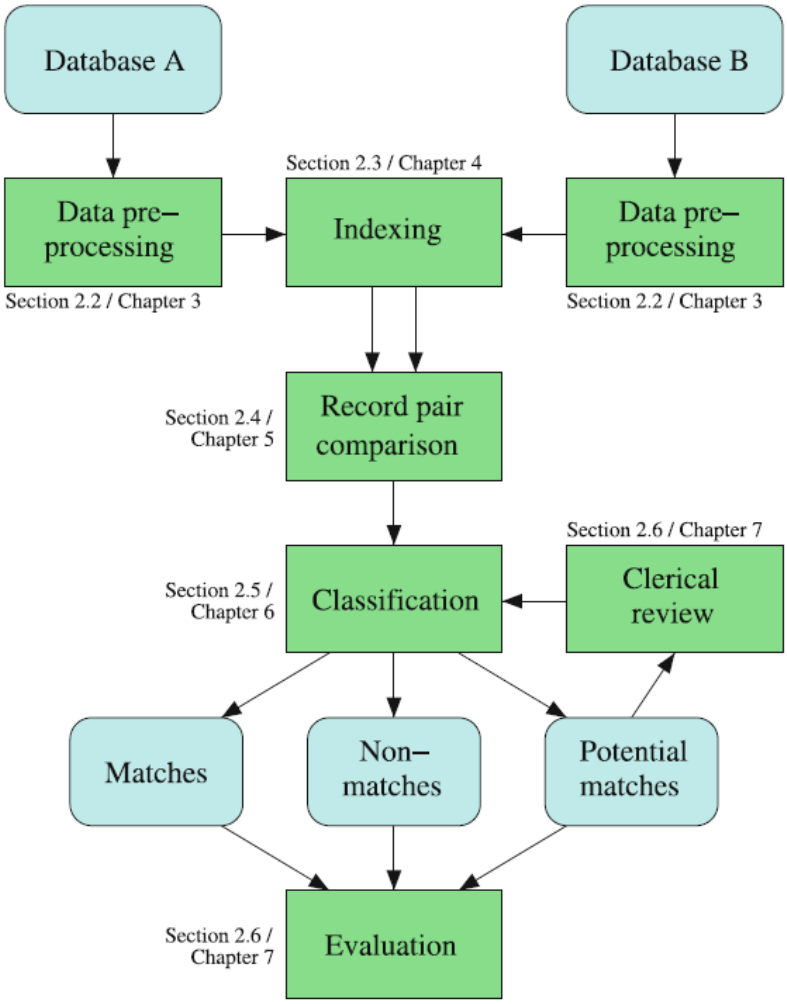


Рис. 2. Типовой процесс связывания записей (предобработка данных, индексация, сравнение пар, классификация и ручная проверка) [3]

Сравнение устойчивости должно учитывать не только средние показатели качества, но и то, насколько эти показатели меняются при одинаковых для всех моделей изменениях данных и условий применения. Для этого задают воспроизводимые сценарии ухудшения качества признаков и изменения статистических свойств данных: увеличение доли пропусков, рост числа опечаток и вариаций написания, перестановки символов, а также изменение распределений значений. Такие ситуации отражают распространённую в машинном обучении проблему сдвига распределения данных, когда распределение данных при обучении и при реальном использовании различается, из-за чего модель может работать менее стабильно. В теоретическом плане устойчивость связывают с чувствительностью алгоритма к изменениям данных и с его способностью сохранять качество обобщения при таких изменениях.

Чтобы сравнение было статистически корректным, результаты рассчитывают на нескольких повторениях/разбиениях и дополняют доверительными интервалами для ключевых интегральных метрик (например, для AUC), используя бутстрэп-оценивание; бутстрэп-подход к доверительным ин-

тервалам AUC описан в прикладной статистике диагностики. На этой основе устойчивость разных вероятностных ID-моделей сравнивают по тому, насколько мало и предсказуемо меняются AUPRC/AUROC и калибровочные показатели при заданных, одинаковых для всех моделей, сценариях изменения данных.

Практическая интерпретация результатов сравнения устойчивости целесообразна через компромисс между полезностью идентификации и уровнем ограничений конфиденциальности: при ужесточении приватностных мер (минимизация полей, деидентификация, добавление случайности) информативность признаков снижается, а вариативность оценок возрастает, что отражается на стабильности решений и вероятностных оценок. Этот общий эффект обычно иллюстрируют как «кривую компромисса приватность–полезность» (рисунок 3), где достижение более высокой приватности сопровождается снижением полезности данных, а допустимая область определяется задачей и риском.

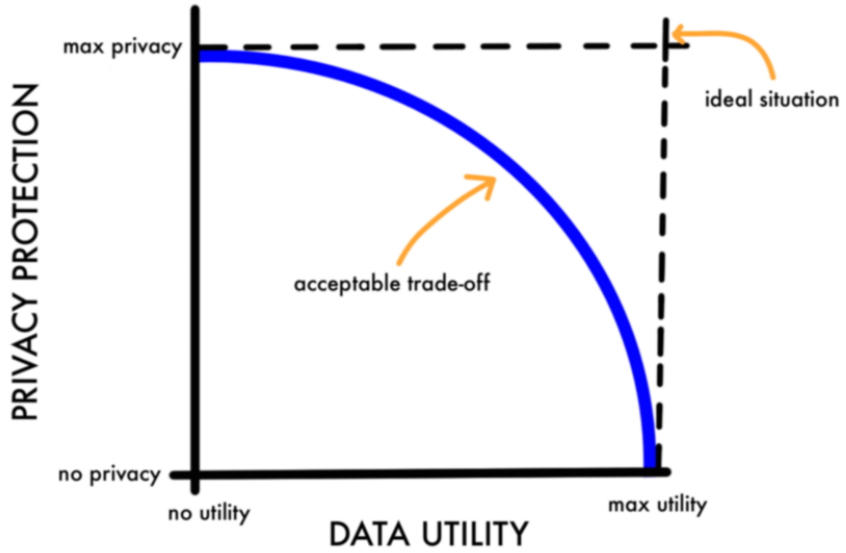


Рис. 3. Компромисс между уровнем защиты конфиденциальности и полезностью данных [5]

Практический вывод из такой постановки заключается в том, что выбор вероятностной ID-модели должен делаться не по одному значению качества, а по тому, насколько предсказуемо модель сохраняет приемлемые показатели при ограничении признаков и при типовых ухудшениях качества данных, а также по тому, насколько контролируемо можно настроить процедуры принятия решений (например, пороги и обработку пограничных случаев) в допустимых режимах доступа.

Выводы

Таким образом, строгие требования к конфиденциальности закономерно усиливают неопределённость в данных и могут снижать стабильность вероятностных оценок и пороговых решений в ID-задачах, особенно при сдвиге распределений и деградации качества полей. Поэтому выбор вероятностной ID-модели должен основываться не на единичном значении качества, а на устойчивости метрик и калибровки в стандартизированных сценариях изменения данных при фиксированных приватностных ограничениях. Предложенная рамка сравнения позволяет сопоставимо оценивать модели в условиях минимизации данных и частных преобразований и формировать практические критерии выбора решений, сохраняющих предсказуемое качество в приватностно-ограниченной среде.

Список литературы

1. A Theory for Record Linkage: Journal of the American Statistical Association: Vol 64, No 328 [Электронный ресурс]. – Режим доступа: https://www.tandfonline.com/doi/abs/10.1080/01621459.1969.10501049.

2. AI Risk Management Framework | NIST [Электронный ресурс]. – Режим доступа: https://www.nist.gov/itl/ai-risk-management-framework.

3. Base de datos corporativa de personas [Электронный ресурс]. – Режим доступа: https://bookdown.org/content/2085/prueba-de-concepto-1.html.

4. GDPR Security Compliance: What Every Company Needs to Know [Электронный ресурс]. – Режим доступа: https://hyperproof.io/resource/gdpr-security-compliance.

5. Trade-off between privacy and utility. | Download Scientific Diagram [Электронный ресурс]. – Режим доступа: https://www.researchgate.net/figure/Trade-off-between-privacy-and-utility_fig2_352683398.

No 178 (178) (2026)

The scientific heritage
(Budapest, Hungary)
The journal is registered and published in Hungary.
The journal publishes scientific studies, reports and reports about achievements in different scientific fields.
Journal is published in English, Hungarian, Polish, Russian, Ukrainian, German and French.
Articles are accepted each month.
Frequency: 24 issues per year.
Format - A4
ISSN 9215 — 0365

All articles are reviewed
Free access to the electronic version of journal
Edition of journal does not carry responsibility for the materials published in a journal.
Sending the article to the editorial the author confirms it's uniqueness and takes full responsibility for possible consequences for breaking copyright laws

Chief editor: Biro Krisztian
Managing editor: Khavash Bernat

- Singula Aleksandra - Professor, Department of Organization and Management at the University of Zagreb (Zagreb, Croatia)
- Bogdanov Dmitrij - Ph.D., candidate of pedagogical sciences, managing the laboratory (Kiev, Ukraine)
- Chukurov Valeriy - Doctor of Biological Sciences, Head of the Department of Biochemistry of the Faculty of Physics, Mathematics and Natural Sciences (Minsk, Republic of Belarus)
- Torok Dezso - Doctor of Chemistry, professor, Head of the Department of Organic Chemistry (Budapest, Hungary)
- Filipiak Pawel - doctor of political sciences, pro-rector on a management by a property complex and to the public relations (Gdansk, Poland)
- Flater Karl - Doctor of legal sciences, managing the department of theory and history of the state and legal (Koln, Germany)
- Bence Orban - Doctor of sociological sciences, professor of department of philosophy of religion and religious studies (Miskolc, Hungary)
- Feld Ella - Doctor of historical sciences, managing the department of historical informatics, scientific leader of Center of economic history historical faculty (Dresden, Germany)
- Owczarek Zbigniew - Doctor of philological sciences (Warsaw, Poland)
- Gál Jenő - MD, assistant professor of history of medicine and the social sciences and humanities (Budapest, Hungary)
- Borbély Kinga - Ph.D, Professor, Department of Philosophy and History (Kosice, Slovakia)
- Eberhardt Mona - Doctor of Psychology, Professor, Chair of General Psychology and Pedagogy (Munich, Germany)
- Kramarchuk Vyacheslav - Doctor of Pharmacy, Department of Clinical Pharmacy and Clinical Pharmacology (Vinnytsia, Ukraine)

«The scientific heritage»
Editorial board address: Budapest, Kossuth Lajos utca 84,1204
E-mail: public@tsh-journal.com
Web: www.tsh-journal.com